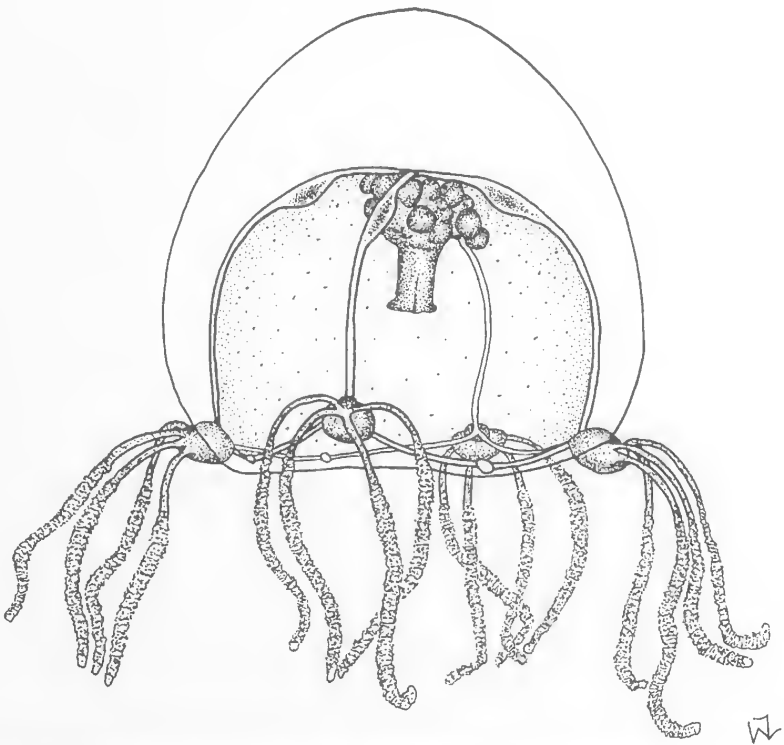


# Records of the Western Australian Museum



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# Records of the Western Australian Museum

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Cover: Female of a new species of *Australomedusa*.

Illustration by W. Zeidler.

# The benthic invertebrate fauna of the Peel-Harvey Estuary of south-western Australia after completion of the Dawesville Channel

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**Abstract** – During the 1970's the Peel-Harvey Estuary experienced severe symptoms of nutrient enrichment. There were large inputs of nutrients to the system, and only limited oceanic flushing occurred, via the long, narrow Mandurah Entrance Channel. In 1994 the Dawesville Channel was constructed to increase oceanic flushing within the Peel-Harvey Estuary; reduce the occurrence of toxic phytoplankton blooms (eg. blue-green *Nodularia spumigena*) and decrease macroalgal growth. The present paper compares the benthic invertebrate fauna in the Peel-Harvey Estuary before and after the Dawesville Channel was constructed.

One hundred sediment cores were collected during early autumn and late winter 2000, yielding a total of 17,443 benthic invertebrates, comprising 52 species. Polychaetes, molluscs and crustaceans dominated species richness and density in both seasons. There was a clear difference in benthic invertebrate species richness and density between seasons. During early autumn, benthic invertebrate communities in the Peel-Harvey Estuary had a low species richness (27 species), but this increased substantially (46 species) in late winter. Total mean density quadrupled from 6397m<sup>-2</sup> in early autumn to 26,180m<sup>-2</sup> in late winter. The increased species richness was due to increases in small crustaceans with a short lifespan and, to a lesser extent, chironomid insect larvae. With the exception of one site, the increased density was general throughout both Peel Inlet and the Harvey Estuary. There was no apparent correlation between increased densities and proximity to the entrance channels.

Pre-Dawesville Channel data on benthic invertebrates are few. Molluscs provided the best comparisons between pre and post Dawesville Channel benthic invertebrates. In the late 1970's mollusc diversity was low and was dominated by two small estuarine species: the bivalve *Arthritica semen* and the gastropod *Hydrococcus brazieri*. A two-year study at one site in Peel Inlet recorded a maximum density of 45,491m<sup>-2</sup> for *A. semen* and 19,959m<sup>-2</sup> for *H. brazieri*. By the 1980's the density of both species had declined; *H. brazieri* had nearly disappeared from the Peel-Harvey Estuary. In 2000, the mean densities of *A. semen* and *H. brazieri* remained low. Several marine species that were recorded in the post Dawesville Channel samples were not recorded in the 1970's. Data suggests that the Peel-Harvey Estuary has become more marine, and that increased recruitment of planktonic larvae through the short, narrow Dawesville Channel and improved water quality has probably enabled these species to establish themselves. All of these species were recorded in very low densities, and they have not established the dense populations previously attained by *H. brazieri* and *A. semen*.

**Key words:** Benthic invertebrates, Peel-Harvey Estuary, Dawesville Channel, Western Australia.

## INTRODUCTION

Estuaries in south-western Australia are generally small, and their physical and geomorphological characteristics make them particularly susceptible

to human impacts (Hodgkin and Lenanton, 1981). While the catchments may have large areas, rainfall is low and water volumes in river inflows are small by world standards. As the river reaches the coastal

plain, many estuaries broaden into shallow lagoons. The lagoons are sedimentary and there are often few hard substrates or rocky bottoms for organisms to colonise. A narrow entrance channel to the sea often restricts tidal flow into and out of the estuary (Hesp, 1984; Hodgkin and Hesp, 1998). Tides in the southwest are microtidal, ranging up to 1m over the year, but averaging 0.3m or less on each tidal cycle (Hodgkin and DiLollo, 1958). Many estuaries have a sand bar across the mouth which restricts water exchange from several months through to years, until the bar is broken; some bars have become permanent, while others are kept permanently open by human intervention (Hodgkin and Hesp, 1998).

The combination of a low riverine input; a large lagoon; narrow channel to the sea, and small tidal amplitude, all serve to minimise exchange between south-western Australian estuaries and the sea, thus concentrating contaminants, mainly nutrients, in the estuaries (Hodgkin and Hesp, 1998).

Rainfall in the southwest is strongly seasonal and Mediterranean, with most occurring from late autumn to early spring (May to September). Estuarine salinities during winter are low, often falling to as low as 3‰ over broad portions of the lagoons and basins, and remaining at those levels for weeks. As rivers cease to flow in spring, tidal intrusion combined with increased evaporation from greater day length and air temperatures, cause the estuaries to become more saline. Hypersaline (>45‰) conditions and high water temperatures can occur over most of the summer and early autumn (Hodgkin and Lenanton, 1981).

As with several other south-western Australian estuaries, the Peel-Harvey Estuary (32°S; 115°E) has been severely affected by nutrient enrichment. The system consists of the circular Peel Inlet, with an area of 75km<sup>2</sup>, and the elongate Harvey Estuary, with an area of 61km<sup>2</sup> (Hodgkin and Lenanton, 1981; Figure 1). The two have similar mean volumes (61 × 10<sup>6</sup>m<sup>3</sup> and 56 × 10<sup>6</sup>m<sup>3</sup> respectively) and shallow water depths, averaging 0.8m and 1.0m respectively (McComb and Lukatelich, 1995). Historically, tidal exchange with the Indian Ocean was restricted by the long, narrow Mandurah Entrance Channel in the north of Peel Inlet, resulting in poor nutrient flushing from the Peel-Harvey Estuary. As agriculture expanded in the catchment and fertiliser usage increased, nutrients progressively accumulated in the Peel-Harvey Estuary. This resulted firstly in large increases in benthic macroalgae followed later by seasonal blooms of harmful phytoplankton (toxic blue-green *Nodularia spumigena*). As a result of extensive environmental studies (eg. Rippingale, 1977; Wells *et al.*, 1980; Hodgkin *et al.*, 1985; Rose, 1994), a short, narrow channel was constructed through the coastal dunes in the northern Harvey Estuary. This

channel, the Dawesville Channel, opened in April 1994 and was designed to increase oceanic flushing within the Peel-Harvey Estuary, raise salinities to create conditions unsuitable for harmful phytoplankton blooms, and decrease macroalgal growth.

The estuarine food chain typically consists of abundant and productive primary producers (macroalgae, seagrasses, and/or phytoplankton), which are grazed by primary consumers such as zooplankton, worms, molluscs, small crustaceans and fish. Benthic species often dominate invertebrate abundance and production in an estuary (Day, 1981; Hodgkin *et al.*, 1985). While individual species may be abundant, species diversity is usually low (Barnes, 1974; McLusky, 1989). Benthic invertebrates are the food source for a wide variety of estuarine fish, large crustaceans and waterbirds, which in turn are available to higher trophic levels (Barnes, 1974; Day, 1981).

Prior to the opening of the Dawesville Channel, few benthic invertebrate species were able to tolerate the environmental conditions in the Peel-Harvey Estuary. These were mainly small, short-lived opportunists that were highly productive (Rippingale, 1977; Wells *et al.*, 1980; Chalmer and Scott, 1984; Rose, 1994). The opening of the Dawesville Channel increased water exchange with the sea and made the Peel-Harvey Estuary a more marine environment. Tides are now of similar amplitude to those along the coast and salinity is less variable. The present paper has two purposes: to characterise the present benthic invertebrate fauna of the Peel-Harvey Estuary and to examine changes which have occurred in the system as a result of the opening of the Dawesville Channel.

## MATERIALS AND METHODS

Samples were collected from ten sites in Peel Inlet and the Harvey Estuary during early autumn (March) and late winter (August) 2000 (Figure 1). To allow direct comparisons, the sample sites and sampling regime were the same as those used in a study of molluscs in the late 1970's (Wells *et al.*, 1980). Site 10 (Dawesville) was chosen to assess the immediate area of the Dawesville Channel. Most sites were 10–15m from shore in water depths of approximately 0.5m. Site 1 (Coodanup), Site 4 (Robert Bay) and Site 6 (Caddadup) were 100m from shore as the water was extremely shallow. Site 5 (located in the mid-region of Peel Inlet) was approximately 2km south of Site 1 and at a water depth of less than 1.5m.

Samples were collected using a 10.3cm diameter PVC tube which was driven into the sediment to a depth of 20cm. Six replicates were taken at each site. Samples were sieved through a 0.5mm mesh in the field. They were labelled and placed in 10%

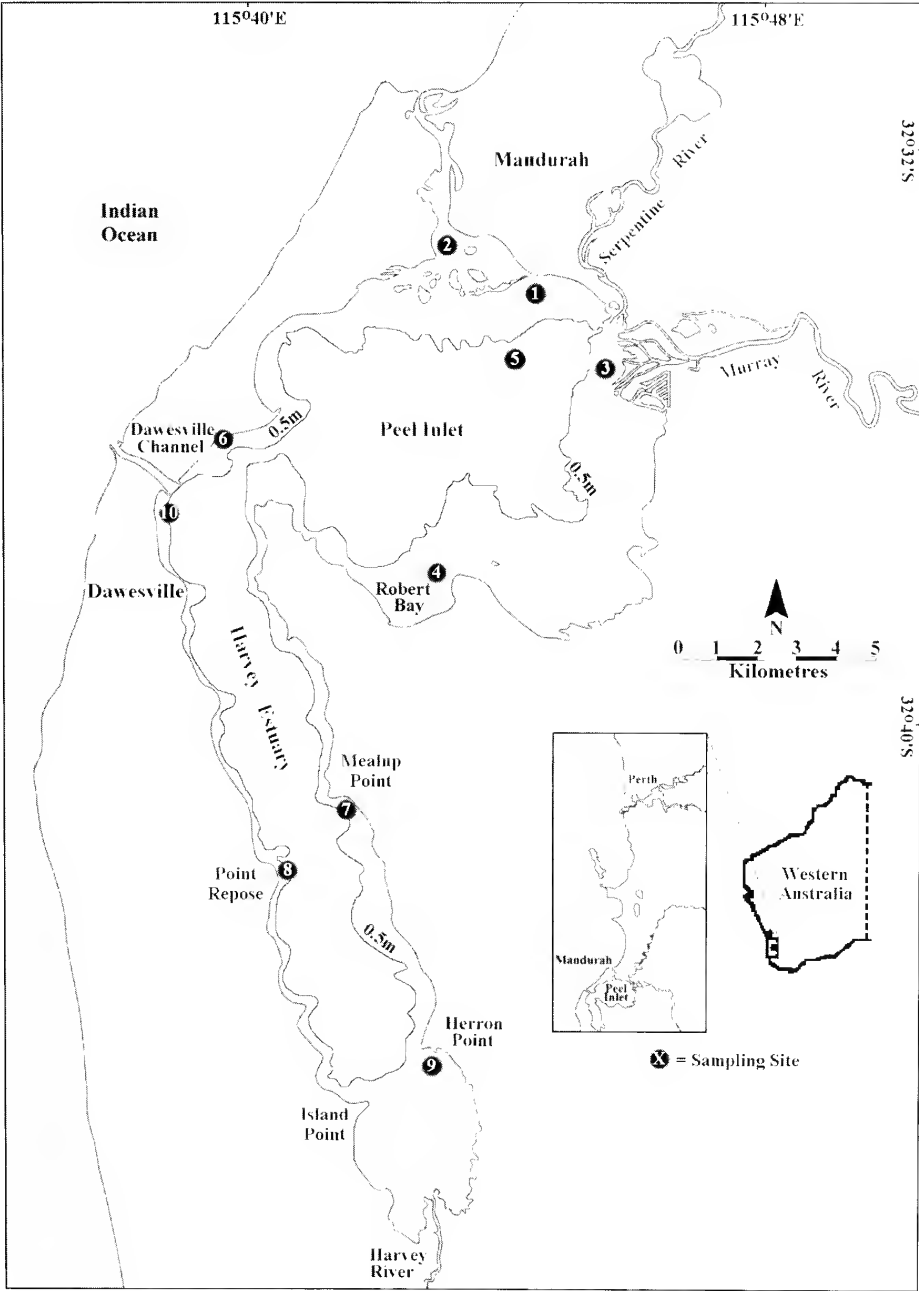


Figure 1 Map of sampling locations in the Peel-Harvey Estuary.

formalin for two weeks before being transferred to 75% alcohol. In the laboratory, samples were sorted under a dissecting microscope. Any invertebrates that were alive when collected were removed, identified, counted and retained in 75% alcohol.

Surface and bottom water temperatures and dissolved oxygen concentrations were measured using an analog YSI 51A oxygen meter, and

salinities were measured using an Atago S/Mill-E refractometer. Sediment samples were also collected for analysis of physical and chemical characteristics. The upper 10cm of sediment was removed using clean PVC tubing and partitioned into two 5cm halves before being stored on ice. One portion from each core was treated with 6% hydrogen peroxide for 48 hours to remove any

organic matter, washed overnight, and dried at 60°C for 24 hours. Sediment grain size and frequency were then determined using a standard set of geological sieves and the Wentworth scale. Particulate organic matter in the remaining portion was determined by removing any macrophyte and animal material from the sediment, drying the sediment at 60°C for 24 hours and burning on ignition at 530°C for 16 hours, then weighing to the nearest 1mg (Holme and McIntyre, 1984). Five replicate cores using clean PVC tubing were taken to a depth of 10cm at each site to determine redox depth as described by Rose (1994).

Dendograms were calculated using the IBM program PC Ord. This program groups sites by cluster analysis using average linkage based on Sorenson's Index of Similarity. Species diversity (H'), evenness (E) and dominance (D) were calculated using the Shannon Weiner formula (Krebs, 1989).

RESULTS

Physical and Chemical Data

Salinity and temperature in the water column were variable between sampling periods (Table 1). All sites were hypersaline in early autumn. Salinity increased with distance from the Dawesville and Mandurah channels. During late winter, salinities were highest at sites located close to the channels, and in the eastern region of Peel Inlet. Salinities were low (<16‰) in the southern regions of Peel Inlet and the Harvey Estuary. In late winter, bottom salinities were generally the same (<1‰ difference) as at the surface except at Site 6, Site 4 and Site 9 (Herron Point), where they greatly exceeded those at the surface (up to 9‰ difference). The surface and bottom water temperatures at all sites varied seasonally, ranging from 23.5°C in early autumn to 14.0°C in late winter (Table 1). There was very little difference (<0.5°C) in bottom and surface water temperatures.

Fauna

One hundred cores were taken during early autumn and late winter 2000, yielding 17,443 benthic invertebrates and a total of 52 species. During early autumn, species richness of benthic invertebrates was low, consisting primarily of polychaetes, molluscs and crustaceans (Table 2). Together the three taxa accounted for 25 of the 27 species recorded and were also the most abundant. Five species comprised 88.4% of total mean density (Table 3): the bivalve *Arthritica semen* (2457m<sup>-2</sup>); the polychaetes *Capitella* aff *capitata* (1657m<sup>-2</sup>), *Ceratonereis aquisetis* (404m<sup>-2</sup>), and *Leitoscoloplos normalis* (298m<sup>-2</sup>), and the amphipod *Corophium minor* (840m<sup>-2</sup>).

Table 1 Environmental and sedimentary measurements made at ten sites in the Peel-Harvey Estuary during early autumn (A) and late winter (W) 2000. As there was little difference between surface and bottom temperatures, dissolved oxygen concentrations and salinities, only surface measurements are shown.

Characteristic		Peel Inlet					Harvey Estuary				
		1	2	3	4	5	6	7	8	9	10
Water temperature (°C)	A	18.0	20.0	23.0	23.5	19.5	20.5	23.2	21.5	21.3	19.5
	W	18.0	16.0	17.9	17.2	17.0	16.5	15.0	16.8	14.0	17.0
Dissolved oxygen (ppm)	A	7.5	6.6	11.2	8.6	6.4	8.5	8.6	7.6	8.4	8.2
	W	9.3	8.9	10.1	11.1	6.9	9.5	10.7	8.6	11.9	9.0
Salinity (‰)	A	39.0	38.0	43.0	44.0	42.0	43.0	44.0	45.0	44.0	38.0
	W	30.0	13.0	21.0	5.0	28.0	17.0	15.0	6.0	6.0	16.0
Redox Depth ± SE (mm)	A	2.0 ± 0.3	63.4 ± 3.7	2.5 ± 0.5	2.2 ± 0.2	4.0 ± 0.4	16.0 ± 1.3	23.0 ± 2.0	28.4 ± 0.8	26.6 ± 1.4	29.0 ± 1.3
	W	3.8 ± 0.4	61.8 ± 2.2	3.8 ± 0.4	0.8 ± 0.1	1.4 ± 0.2	7.2 ± 0.4	15.8 ± 1.1	50.8 ± 4.5	27.0 ± 1.3	28.4 ± 1.1
Particulate Organic Matter (%)	A	0.51	0.37	0.91	2.49	0.97	0.43	0.24	0.37	0.22	0.76
	W	1.63	0.44	0.86	2.41	0.91	0.48	0.19	0.65	0.17	0.84

**Table 2** Number of species, mean density and percentage contribution of major taxonomic groups in the Peel-Harvey Estuary during early autumn and late winter 2000.

Taxon	Number of Species	Early Autumn		Number of Species	Late Winter	
		Mean Density m <sup>-2</sup> (X ± SE)	Contribution (%)		Mean Density m <sup>-2</sup> (X ± SE)	Contribution (%)
Polychaeta	9	2777 ± 272	43.4	10	11,232 ± 890	42.9
Mollusca	9	2587 ± 711	40.5	11	2545 ± 444	9.7
Crustacea	7	1028 ± 237	16.1	18	8465 ± 1621	32.3
Insecta	1	2 ± 2	>0.0	3	3916 ± 1107	15.0
Coelenterata	1	2 ± 2	>0.0	2	10 ± 5	>0.0
Priapulida	0	0 ± 0	>0.0	1	8 ± 8	>0.0
Echinodermata	0	0 ± 0	>0.0	1	2 ± 2	>0.0
Nemertea	0	0 ± 0	>0.0	1	2 ± 2	>0.0
<b>Total</b>	<b>27</b>	<b>6397 ± 1224</b>	<b>100.0</b>	<b>46</b>	<b>26,180 ± 4079</b>	<b>100.0</b>

Species richness was substantially greater (46 species) in late winter. As in autumn, polychaetes, molluscs and crustaceans dominated, with an increase of 11 crustacean species. In addition, a single species each of priapulid, echinoderm and nemertean were found in late winter; none were recorded in early autumn. Total mean invertebrate density quadrupled to 26,180m<sup>-2</sup> in late winter compared to 6397m<sup>-2</sup> in early autumn. Molluscs had approximately the same density in early autumn and late winter, but polychaetes and crustaceans increased substantially, by 8455m<sup>-2</sup> and 7437m<sup>-2</sup> respectively. In contrast to their near absence in early autumn, the density of insects in late winter was 3416m<sup>-2</sup>. In late winter the five most abundant species comprised only 73.5% of the total mean density. They were the polychaete *Capitella* aff *capitata* (7015m<sup>-2</sup>), the amphipods *Corophium minor* (4304m<sup>-2</sup>) and *Paracorophium excavatum* (2129m<sup>-2</sup>), a chironomid larva (3902m<sup>-2</sup>) and the bivalve *Arthritica semen* (1895m<sup>-2</sup>).

Distribution of species in the estuary was uneven (Table 4; Figure 1). In early autumn the number of species varied from one at Site 4 and two at Site 3 (South Yunderup) to 15 at Site 2 (Mandurah Entrance Channel); all of these sites are in Peel Inlet. Species were more evenly distributed throughout all sites in the Harvey Estuary, ranging from seven species at Site 7 (Mealup Point) to nine species at Site 10. With the exception of Site 9, all other sites had more species in late winter. There was also an increased variability in species distributions. In Peel Inlet, the number of species ranged from eight at Site 4 to 26 at Site 6. The range in the Harvey Estuary was from six species at Site 9 to 23 species at Site 8 (Point Repose).

Similarly, there were considerable variations in the total invertebrate density between sites (Table 4; Figure 1). The minimum total mean density recorded in early autumn was 20m<sup>-2</sup> at Site 4 in Peel Inlet; the maximum was 24,690m<sup>-2</sup> at Site 9 in the Harvey Estuary. In contrast to species richness, total

mean density variations in the Harvey Estuary were greater in early autumn (from 1060m<sup>-2</sup> at Site 10 to 24,690m<sup>-2</sup> at Site 9) than in Peel Inlet (20m<sup>-2</sup> at Site 4 to 9824m<sup>-2</sup> at Site 5). Total mean densities increased in late winter at all sites except Site 9 in the Harvey Estuary, where density decreased from 24,690m<sup>-2</sup> to 13,705m<sup>-2</sup>. Mean invertebrate density at Site 8 in the Harvey Estuary increased by 26-fold, from 2201m<sup>-2</sup> in early autumn to 58,083m<sup>-2</sup> in late winter. Densities at Sites 3 and 6 in Peel Inlet also increased by over an order of magnitude. The greatest percentage increase occurred at Site 4 in Peel Inlet, where densities increased by nearly three orders of magnitude, from 20m<sup>-2</sup> to 17,287m<sup>-2</sup>. There was no clear relationship between invertebrate density and proximity to the Dawesville Channel. In particular, Site 6 near the northern end of the Harvey Estuary had a total mean density of 53,942m<sup>-2</sup> in late winter, while the nearby Site 10 at the entrance to the Dawesville Channel had a total mean density of only 8403m<sup>-2</sup>.

Most of the increase in total mean density in late winter was due to five species: the polychaete *Capitella* aff *capitata* increased in mean density from 1657m<sup>-2</sup> in early autumn to 7015m<sup>-2</sup> in late winter; the amphipods *Corophium minor* from 840m<sup>-2</sup> to 4304m<sup>-2</sup> and *Paracorophium excavatum* from 0m<sup>-2</sup> to 2129m<sup>-2</sup>; an unidentified chironomid larva from 0m<sup>-2</sup> to 3902m<sup>-2</sup>; and the isopod *Tanais dulongi* from 0m<sup>-2</sup> to 998m<sup>-2</sup>. Except for the chironomid larva, all of these are estuarine species. The estuarine bivalve *Arthritica semen* decreased in density from 2457m<sup>-2</sup> in early autumn to 1895m<sup>-2</sup> in late winter.

Cluster analysis indicated there were no clear community differences in the invertebrate community in different parts of the estuary (Figure 2). In early autumn there was some separation of invertebrate communities in the Peel Inlet and Harvey Estuary between Sites 6 and 10, near the entrance to the Dawesville Channel. Site 4 in Peel Inlet was the exception, due to the occurrence of only one species at this site, Anthicidae sp., a

**Table 3** Mean density of benthic invertebrate species collected in the Peel-Harvey Estuary during early autumn and late winter 2000.

Taxon	Mean Density m <sup>-2</sup> ( $\bar{X} \pm \text{SE}$ )	
	Early Autumn	Late Winter
<b>POLYCHAETA</b>		
<i>Australonereis ehlersi</i> Augener, 1913	170 $\pm$ 56	812 $\pm$ 200
<i>Boccardiella limnicola</i> Blake & Woodwick, 1976	108 $\pm$ 30	326 $\pm$ 93
<i>Capitella</i> aff. <i>capitata</i> Fabricius, 1780	1657 $\pm$ 224	7015 $\pm$ 839
<i>Ceratonereis acquisetis</i> Augener, 1913	404 $\pm$ 93	856 $\pm$ 133
<i>Heteromastus filiformis</i> (Claparede, 1864)	52 $\pm$ 19	22 $\pm$ 8
<i>Laonome</i> sp.	66 $\pm$ 14	1056 $\pm$ 214
<i>Leitoscoloplos normalis</i> Day, 1977	298 $\pm$ 69	812 $\pm$ 112
<i>Marphysa sanguinea</i> Montague, 1815	12 $\pm$ 7	6 $\pm$ 4
<i>Nephtys gravieri</i> Augener, 1913	10 $\pm$ 5	0 $\pm$ 0
<i>Nephtys longipipes</i> Stimpson, 1856	0 $\pm$ 0	4 $\pm$ 3
<i>Spirorbidae</i> sp.	0 $\pm$ 0	322 $\pm$ 109
<b>Total Polychaetes</b>	<b>2777 <math>\pm</math> 272</b>	<b>11,232 <math>\pm</math> 890</b>
<b>MOLLUSCA</b>		
<b>Bivalvia</b>		
<i>Arthritica senen</i> (Menke, 1843)	2457 $\pm$ 711	1895 $\pm$ 421
<i>Donax columbella</i> Lamarck, 1818	0 $\pm$ 0	12 $\pm$ 6
<i>Sanguinolaria biradiata</i> (Wood, 1815)	2 $\pm$ 2	2 $\pm$ 2
<i>Spisula trigonella</i> (Lamarck, 1818)	4 $\pm$ 3	344 $\pm$ 104
<i>Tellina deltoidalis</i> Lamarck, 1818	2 $\pm$ 2	26 $\pm$ 10
<b>Gastropoda</b>		
<i>Acteocina</i> sp.	80 $\pm$ 43	72 $\pm$ 29
<i>Assiminea</i> sp.	8 $\pm$ 4	26 $\pm$ 8
<i>Hydrococcus brazieri</i> (T. Woods, 1876)	30 $\pm$ 15	134 $\pm$ 40
Cephalaspidean sp.	0 $\pm$ 0	10 $\pm$ 4
<i>Nassarius burchardi</i> (Philippi, 1849)	2 $\pm$ 2	16 $\pm$ 7
<i>Hydrobia buccinoides</i> (Quoy & Gaimard, 1834)	0 $\pm$ 0	8 $\pm$ 5
<i>Patella peronii</i> Blainville, 1825	2 $\pm$ 2	0 $\pm$ 0
<b>Total Molluscs</b>	<b>2587 <math>\pm</math> 711</b>	<b>2545 <math>\pm</math> 444</b>
<b>CRUSTACEA</b>		
<b>Isopoda</b>		
<i>Cirolana</i> sp.	0 $\pm$ 0	2 $\pm$ 2
<i>Cruranthura simplicia</i> Thomson, 1946	2 $\pm$ 2	80 $\pm$ 26
<i>Gastrosaccus</i> sp.	4 $\pm$ 3	10 $\pm$ 5
<i>Munna brevicornis</i> (Thomson, 1946)	2 $\pm$ 2	0 $\pm$ 0
<i>Tanais dulongi</i> Thomson, 1944	0 $\pm$ 0	998 $\pm$ 375
<b>Copepoda</b>		
<i>Harpacticoida</i> sp.	0 $\pm$ 0	26 $\pm$ 12
<b>Amphipoda</b>		
<i>Allorchestes</i> cf. <i>compressa</i> Dana, 1852	0 $\pm$ 0	10 $\pm$ 4
<i>Caprella scaura</i> Templeton, 1836	42 $\pm$ 19	0 $\pm$ 0
<i>Corophium minor</i> (Thomson, 1946)	840 $\pm$ 205	4304 $\pm$ 1226
cf. <i>Erichthonius</i> sp.	0 $\pm$ 0	12 $\pm$ 12
<i>Grandidierella</i> sp.	110 $\pm$ 34	638 $\pm$ 119
<i>Lysianassidae</i> sp.	0 $\pm$ 0	2 $\pm$ 2
<i>Melita matilda</i> J.L. Barnard, 1972	0 $\pm$ 0	2 $\pm$ 2
<i>Melita zeylanica</i> J.L. Barnard, 1972	28 $\pm$ 13	174 $\pm$ 47
<i>Paracorophium excavatum</i> (Thomson, 1884)	0 $\pm$ 0	2129 $\pm$ 785
<i>Parelasomopus</i> sp.	0 $\pm$ 0	64 $\pm$ 64
<i>Tethygenia elanora</i> J.L. Barnard, 1972	0 $\pm$ 0	4 $\pm$ 3
<b>Decapoda</b>		
<i>Galathea</i> sp.	0 $\pm$ 0	2 $\pm$ 2
cf. <i>Metapenaeus dalli</i> Racek, 1957	0 $\pm$ 0	2 $\pm$ 2
cf. <i>Penaeus latisulcatus</i> Kishinouye, 1896	0 $\pm$ 0	6 $\pm$ 6
<b>Total Crustaceans</b>	<b>1028 <math>\pm</math> 237</b>	<b>8465 <math>\pm</math> 1621</b>



Taxon	Mean Density m <sup>-2</sup> ( $\bar{X} \pm \text{SE}$ )	
	Early Autumn	Late Winter
INSECTA		
Anthicidae sp.	2 ± 2	0 ± 0
Chironomidae sp. (larva)	0 ± 0	3902 ± 1106
Diptera sp.1 (larva)	0 ± 0	10 ± 7
Diptera sp.2 (larva)	0 ± 0	4 ± 4
Total Insects	2 ± 2	3916 ± 1107
COELENTERATA		
<i>Haliplanella luciae</i> (Verrill, 1898)	2 ± 2	8 ± 5
Pennatulacean sp.	0 ± 0	2 ± 2
PRIAPULIDA		
cf. <i>Priapul</i> sp.	0 ± 0	8 ± 8
ECHINODERMATA		
<i>Astropecten</i> sp.	0 ± 0	2 ± 2
NEMERTEA		
Nemertean sp.	0 ± 0	2 ± 2
Overall Total	6397 ± 1224	26,180 ± 4079

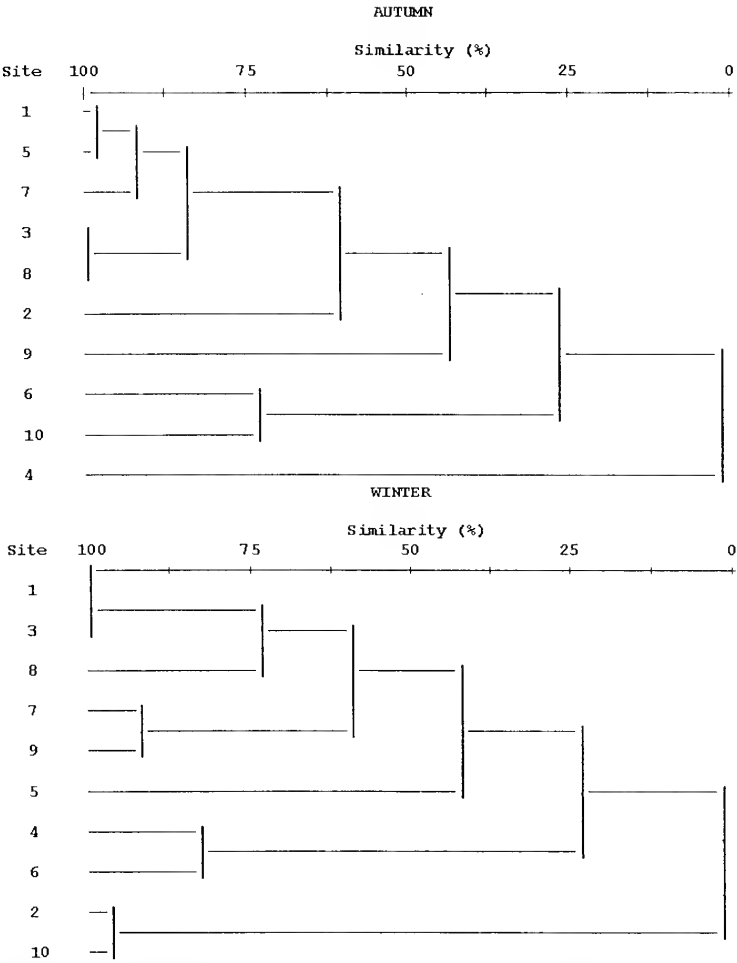


Figure 2 Dendrogram of sampling sites during early autumn and late winter 2000.

**Table 4** Invertebrate populations at each site sampled in the Peel-Harvey Estuary during early autumn and late winter 2000. Shannon-Weiner diversity (H'), Pielou's evenness (E) and Dominance (D).

Characteristic	Peel Inlet					Harvey Estuary				
	1	2	3	4	5	6	7	8	9	10
Early Autumn										
Number of Species	6	15	2	1	11	11	7	8	8	9
Mean Density m <sup>-2</sup>	4382 ± 702	6743 ± 598	2141 ± 477	20 ± 20	9824 ± 1798	3762 ± 600	9144 ± 761	2201 ± 342	24,690 ± 1077	1060 ± 192
H'	0.967	3.104	0.134	0.000	2.066	2.586	1.887	1.787	1.302	2.738
E	0.374	0.794	0.134	0.000	0.597	0.747	0.672	0.596	0.434	0.864
D	0.626	0.206	0.866	1.000	0.403	0.253	0.328	0.404	0.566	0.136
Dominant Species	C. aff capitata C. minor	C. minor A. eltersi	C. aff capitata Assimineca sp.	Anthicidae sp.	C. aff capitata C. minor	A. semen Acteocina sp.	A. semen C. aff capitata	C. aff capitata L. normalis	A. semen C. minor	H. filiformis A. eltersi
Late Winter										
Number of Species	16	23	17	8	19	26	12	23	6	16
Mean Density m <sup>-2</sup>	21,088 ± 2277	17,047 ± 2794	27,010 ± 2364	17,287 ± 2105	27,571 ± 4524	53,942 ± 5818	17,667 ± 1255	58,083 ± 5332	13,705 ± 2100	8403 ± 691
H'	1.632	3.121	1.503	1.143	1.964	2.703	2.437	2.303	1.342	2.676
E	0.408	0.690	0.368	0.381	0.462	0.575	0.680	0.509	0.519	0.669
D	0.592	0.310	0.632	0.619	0.538	0.425	0.320	0.491	0.481	0.331
Dominant Species	C. aff capitata C. minor	Laonome sp. B. limicola	C. aff capitata C. minor	Chironomid sp. C. aff capitata	P. excavatum C. aff capitata	Chironomid sp. T. dilongi	C. aff capitata A. semen	C. minor C. aff capitata	A. semen C. aff capitata	Laonome sp. Grandicrrella sp.

species that did not occur elsewhere. The separation between sites in Peel Inlet and in the Harvey Estuary from those near the Dawesville Channel did not occur in late winter (Figure 2). There was a slight separation between Site 10, at the entrance to the Dawesville Channel, and Site 2 at the entrance to the Mandurah Channel from those further into the estuaries, but Site 6 (near Site 10) was not in this grouping.

## DISCUSSION

The benthic invertebrate assemblage in the Peel-Harvey Estuary had low species richness (27 species) in early autumn. Species richness was substantially greater (46 species) in late winter. Total mean density quadrupled from  $6397\text{m}^{-2}$  in early autumn to  $26,180\text{m}^{-2}$  in late winter and there were no clear differences in community structure in the system in either season. Polychaetes, molluscs and crustaceans dominated species numbers and density in both seasons. The increased species richness in late winter was primarily due to an increase in diversity of small crustaceans with a short life-span (isopods and amphipods) and, to a lesser extent, a chironomid larvae. Thus there is a clear difference of benthic invertebrate species richness and density between the autumn and winter seasons. With the exception of Site 9 (at the southern end of the Harvey Estuary) the increase in density was consistent throughout both Peel Inlet and the Harvey Estuary; there was no apparent correlation between increased densities and proximity to the entrance channels.

Comparison of the present results with benthic invertebrate populations prior to the construction of the Dawesville Channel is difficult as there is little published data available. The best data are those of a three-year study of molluscs conducted during the late 1970's (Wells *et al.*, 1980), at a time when massive amounts of the green macroalga *Cladophora* were present in the system. Mollusc diversity was low (Wells *et al.*, 1980; Wells and Threlfall, 1980; 1981), and was dominated by two small estuarine species: the bivalve *Arthritica semen* and the gastropod *Hydrococcus brazieri*, which together accounted for almost all of total mollusc density on sand in the Peel-Harvey Estuary. Both were found to be small, short-lived species with successful reproductive strategies suitable for estuarine conditions (i.e. fast maturation, continuous egg production and direct development enabling release of juveniles during optimum estuarine conditions). The populations were also highly productive, but densities varied greatly (Wells and Threlfall, 1982a; 1982b; 1982c). A two-year study undertaken at Coodanup in Peel Inlet (near Site 1) from March 1977 to February 1979 recorded a maximum density of  $45,491\text{m}^{-2}$  (mean

$8105\text{m}^{-2}$ ) for *A. semen* and  $19,959\text{m}^{-2}$  (mean  $9487\text{m}^{-2}$ ) for *H. brazieri*.

The middle regions of the Peel-Harvey Estuarine basins were sampled by Rose (1994) in 1986–87, before the Dawesville Channel was constructed. He sampled two sites each in the Peel Inlet and northern Harvey Estuary and recorded 37 species, with macrobenthic densities being highest in autumn and lowest in summer. The benthic fauna in 1986–87 was dominated by small, short-lived opportunist species with successful reproductive strategies suitable for estuarine conditions, eg. the polychaete *Capitella* aff. *capitata*, amphipod *Corophium minor* and bivalve *Arthritica semen*. *Hydrococcus brazieri* was absent in the middle regions of Peel Inlet and, compared to previous sampling (Wells and Threlfall, 1982a; 1982b; 1982c), the density of *A. semen* had decreased, particularly in Peel Inlet. An extensive search failed to reveal any live *H. brazieri*. These low densities were attributed to the deleterious effects of macroalgal and *Nodularia spumigena* decomposition.

The samples taken in 2000 recorded system-wide mean densities of  $30\text{m}^{-2}$  for *H. brazieri* in early autumn and  $134\text{m}^{-2}$  in late winter, compared with a similar survey undertaken in January ( $122\text{m}^{-2}$ ) and August 1978 ( $835\text{m}^{-2}$ ) before the Dawesville Channel was opened. The system-wide mean densities of *A. semen* in early autumn and late winter 2000 were  $2457\text{m}^{-2}$  and  $1895\text{m}^{-2}$  respectively; compared with January ( $7175\text{m}^{-2}$ ) and August ( $1937\text{m}^{-2}$ ) 1978. Whilst the present-day distribution of both species resembles that recorded in the 1970's (Wells and Threlfall, 1982c) densities have remained low since the Dawesville Channel was opened. The reappearance of both species may be attributed to the absence of *Nodularia spumigena* blooms since the opening of the Dawesville Channel and reduced decomposition and smothering by macroalgae, which began to decline in the early 1990's (Hale and Paling, 1999).

The present study recorded a total of 52 species of benthic invertebrates; considerably higher than previous studies undertaken prior to the opening of the Dawesville Channel. Chalmer and Scott (1984) and Rose (1994) found 25 and 37 species respectively. Several marine species were recorded in 2000 that were not common or recorded prior to the opening of the Dawesville Channel, including the molluscs *Donax columbella*, *Nassarius burchardi*, *Patella peronii* and a cephalaspidean species. All of these species were recorded in very low densities, and they have not established the dense populations previously attained by *H. brazieri*.

The Dawesville Channel appears to allow greater access for planktonic larvae to enter the system (as opposed to the narrow shallow Mandurah Entrance Channel) and combined with the increase in salinities during winter, allows marine species, at

least initially, to settle and colonise areas in the estuary in late winter. Seasonal density patterns of benthic invertebrates in this study were different to previous studies by Rose (1994), suggesting the effects of eutrophication are less severe since the Dawesville Channel was constructed. Whether these new marine "non-estuarine" species can survive throughout the year has not yet been determined, although autumn data presented in this study suggests that few of these species maintained their earlier populations. Other factors such as biological interactions eg. fish predation, and benthic competition, may now also influence seasonal density patterns.

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## Comparisons of ground vertebrate assemblages in arid Western Australia in different seasons and decades

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**Abstract** – Assemblages of mammals, reptiles and frogs were sampled 20 years apart on the same five Eastern Goldfields sites and in the same months using the same techniques for the same periods of time. None of nine species of snakes were captured on both surveys and three additional species of lizard were added to the 32 recorded on the first survey. No new mammal or frog species were recorded but the relative abundance of most vertebrate species changed over two decades. The greatest change in relative abundance occurred in a group of lizards that are long lived – the geckos. All sampling sites continued to show an increase in species richness with continued sampling time. Differences in assemblages were greatest between surveys and least between seasons suggesting long-term changes occurred in assemblage structure.

### INTRODUCTION

The first approach to defining biodiversity usually comes from examining species lists derived variously from the literature or biological surveys. These species lists form the basis of identifying areas of high biodiversity and their significance to conservation at spatial scales ranging from global (Myers *et al.*, 2000) to regional (Gomez de Silva and Medellin, 2001) or evaluating the impacts of development on local environments (WA Government, 2002). The adequacy of these lists to accurately determine species richness is seldom assessed, particularly for faunal groups.

The vertebrate fauna of the arid zone of Western Australia has been documented by several broad scale surveys over the last 30 years that have shown inland regions to be biologically diverse, particularly for reptiles (Burbidge *et al.*, 1976, McKenzie and Burbidge, 1979; McKenzie and Robinson, 1987). The vertebrate diversity of the Eastern Goldfields region was examined in more detail by a major biological survey in the late 1970s to early 1980s (Biological Surveys Committee, 1984) resulting in the publication of 12 reports outlining the diversity of vascular plants and vertebrates at over 120 sites in the region. Recent work by environmental consultants has confirmed the diversity of the vertebrate fauna of the Goldfields by undertaking further intensive site-specific samplings but within a longer temporal framework (Thompson and Thompson, 2002). These studies have revealed a larger number of rare species as well as several species that occur well outside their previously known ranges.

As part of a recent biodiversity audit of the Eastern Goldfields, the Kalgoorlie regional office of the Department of Conservation and Land Management (CALM) commenced a program in 2001 to document the vertebrate diversity of pastoral leases that have been acquired for conservation purposes. The first local survey of vertebrate fauna was undertaken on Goongarrie Station and one objective of the survey was to resample five sites that had been sampled in 1978–1981 by the Western Australian Museum during the survey of the Eastern Goldfields (Dell *et al.*, 1988).

This paper describes changes in the composition and relative abundances of the ground faunal assemblages of these five habitats sampled 20 years apart but in the same seasons.

### SURVEY LOCATIONS AND METHODS

In the early 1990s the Department of Conservation and Land Management commenced an acquisition program of leasehold properties to add to the State's conservation reserves. Early amongst these was Goongarrie Station, acquired in 1995 as a property that spanned the major biogeographic feature of the Mulga- Eucalypt line that delineates the South West Interzone and Eremaean Province of Beard (1980) and forms the boundary between the Murchison and Coolgardie Bioregions (Thackway and Cresswell, 1995).

#### Study Area and Sampling Sites

The broad vegetation and soil characteristics of the study area and the five sampling sites

reexamined in this paper are described in detail in Dell *et al.* (1988). Codes for the eastern Goldfields survey were based on a sites' location in the 1:250000 topographical map series, in this case the Edjudina and Menzies [Em] sheets. The sampling of the five sites in each of the CALM and Museum surveys are identified as GS and GG, respectively. The brief descriptions of the five re-sampled sites are as follows:

Em3=GG26=GS26: *Acacia coolgardiensis* Tall Shrubland on Dunefield landform unit with red loamy sand to greater than 3 m.

Em13=GG27=GS27: *Eucalyptus leptopoda* Mallee on Sandplain landform unit with yellowish red sandy loams to 40 cm with gravels below.

Em22=GG28=GS28: *Eucalyptus concinna* Mallee on Broad Valley landform unit with dark red sandy loam to >80cm.

Em21=GG29=GS29: *Casuarina pauper* Low Woodland on Broad Valley landform unit with shallow calcareous earths to > 1m.

Em15=GG30=GS30: *Acacia stowardii* Tall Shrubland on Undulating Plain landform unit with dark red brown loam or clay loam to 10cm and quartz and calcrete below

Sampling sites were selected, in the first instance, to cover the gradient of landform and soil types in a catena from an outlying sand dune to the loams on a quartzite rise in broad valley.

There was no evidence that any of the sites have been subjected to fire between the two surveys while grazing has continued, albeit at a very low level, on both sites 29 and 30 throughout the period.

### Survey and Sampling Periods

Two major surveys and four discrete sampling periods have been undertaken on the five sampling sites. The Western Australian Museum sampled the five sites over six days between 10–15 March 1979 and 6–11 October 1980, while CALM sampled the same sites for seven or six days, respectively, between 24–30 October 2001 and 6–11 March 2002.

The sampling periods of the CALM survey were selected to represent the two main periods of faunal activity in the semiarid of Western Australia [spring (October) and late summer (March)] and be comparative with the earlier study by the Museum. A third sampling of five days was undertaken by the Museum in July 1981, however, data for this winter period are not included as few ground vertebrate species were captured and none that were not already known for the sites (Dell *et al.* 1988).

Sampling at all sites involved the use of pitfall traplines with drift fences, Elliott mammal traps and extensive opportunistic sampling that included both foraging and headtorching techniques. Sampling at GG30 by the Museum did not involve

the use of fenced pitfall traps but extensive opportunistic searching and mammal trapping occurred around a campsite based on this location allowing a comparison of assemblage structure and abundances.

The majority of captures from the Museum's survey were vouchered into the State's collections while less than five percent of the CALM survey individuals were vouchered.

### Analysis

Comparisons between sampling sites and surveys were made using the Bray – Curtis coefficient of dissimilarity for species abundance data and principal co-ordinates plot of these matrices.

How (1998) indicated that upwards of 50 days of sampling are required to sample 70% of a reptile assemblage on the Swan Coastal Plain and this was due to the infrequent capture rates of snakes in particular. However, when only lizards were considered, over 60% of the assemblage was captured after 30 days. As only 25 days of sampling occurred during the four sampling periods of the two surveys, only the lizard assemblages are compared between sampling periods and sites for this study.

The calculation of the magnitude of change in lizard abundances between surveys was calculated following the methods of Pianka (1986). This involved calculating the proportion of the total captures for each taxon in each survey and comparing the change in this proportion between surveys by dividing the larger proportion by the smaller.

## RESULTS

### Assemblage Composition

The abundance and location of all ground vertebrate species captured at Goongarrie during each survey and at each sampling site are presented in Table 1.

### Amphibians and Reptiles

The CALM survey of 2001–2002 added three species of lizard [*Strophurus assimilis*, *Underwoodisaurus milii*, *Varanus tristis*] and six snakes [*Ramphotyphlops australis*, *R. bituberculatus*, *R. hamatus*, *Brachyuophis fasciolata*, *B. semifasciata*, *Simoselaps bertholdi*] to the previously known assemblage. Conversely, eight lizards [*Gehyra purpurascens*, *Heteronotia binoei*, *Delma butleri*, *Pygopus nigriceps*, *Cryptoblepharus carnabyi*, *Cyclodomorphus melanops*, *Egernia formosa*, *Morethia butleri*] and three snakes [*Demansia psammophis*, *Parasuta monachus*, *Pseudonaja modesta*] were captured during the Museum survey in 1979–1980 that were not recorded during the CALM survey.

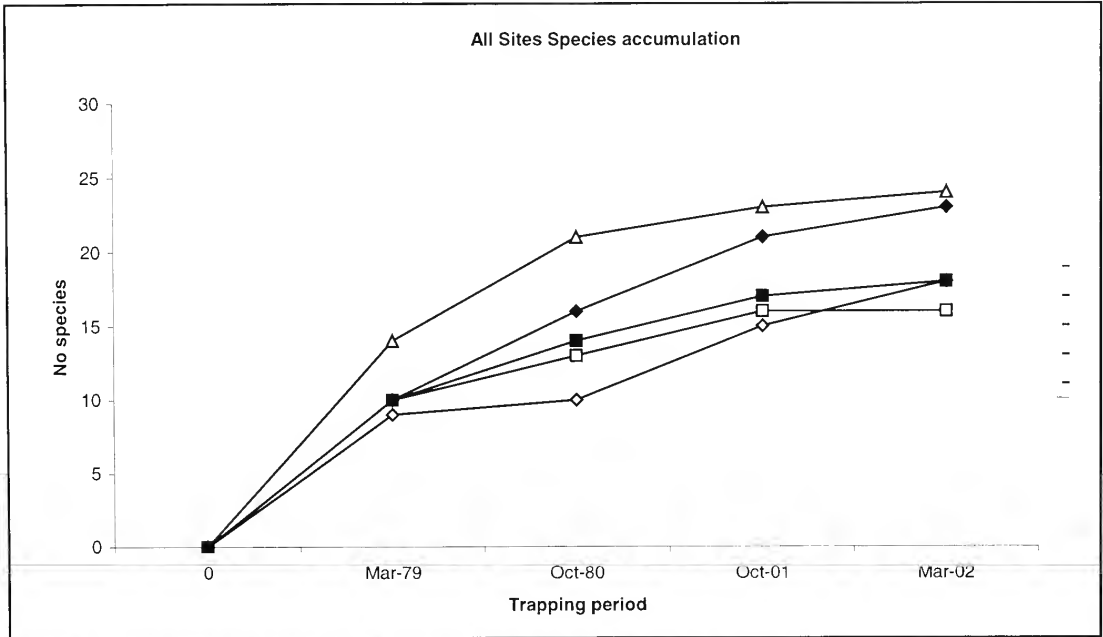


Figure 1 Species accumulation for the five sampling sites over the four sampling periods

No additional species of frogs were recorded during the CALM survey, such that 2 amphibian and 44 reptile species are now recorded from the five sites.

The cumulative total of species recorded for each sampling site over the four sampling periods is presented in Figure 1. On all sites, additional species continued to be caught during the last survey period, March 2002, indicating that further species should continue to be recorded with future sampling. Particularly, additional species of snakes could be expected as their cryptic nature, low density and seasonal activity make them very difficult to document over short duration surveys such as those undertaken to date.

#### Mammals

Seven species of ground mammal were recorded during the Museum's survey. The CALM survey did not record additional species but added species to the assemblages of individual sites (Table 1). Of particular significance was the high number of juvenile individuals of most species recorded during the March 2002 survey.

#### Lizard Assemblages

Table 1 indicates that neither of the two frogs nor any of the nine species of snakes were recorded on both Museum and CALM surveys, consequently only the lizards were considered in changes in relative abundances between the two surveys.

Thirty-two lizards with 278 records were documented on the Museum survey while 27

species with 178 records were recorded on the CALM survey. Of the combined 35 lizard species recorded, 19 decreased in relative abundance and 16 increased between the surveys (Table 1). The mean change in relative abundance of the 24 species in common between both surveys was  $2.74 \pm 2.84(24)$  times. The relative abundance of the lizard fauna on each survey is presented in Figure 2.

Comparisons between the lizard assemblages of the four sampling periods, using the Bray-Curtis distance index, showed the CALM sampling of March and October were most similar to one another (Table 2) and were also more similar to the Museum's March survey than any were to the Museum's October assessment (Figure 3). These differences are accounted for by marked changes in the abundance of species between sampling periods, especially for the Museum's October sampling (Table 1).

Comparison between the lizard assemblages on sampling sites between the two surveys using abundance data (Table 3) showed the most similar site between the two surveys was Site 29 ( $0.471$ ) while the least similar sites was Site 30 ( $0.761$ ). The mean dissimilarity between sites [ $0.560 \pm 0.12(5)$ ] sampled 20 years apart was less than the dissimilarity among sites [ $0.707 \pm 0.16(40)$ ] over the same period. Figure 4 details the relationship between sites over the two surveys, using principal co-ordinates analysis, and indicates that three main groupings occur on axis 1 that represent 39% of the variation and reflect the main soil types. Sites 26, 27 and 28 are habitats on sands and sandy gravels,

**Table 1** The number of individuals of each species of ground vertebrate fauna recorded on the five sample sites during each survey. The change in relative abundance is also presented for lizard taxa.

TAXON	GC26 300	GC27 240	GC28 120	GC29 120	GC30 780	Total GG	GS26 156	GS27 156	GS28 156	GS29 156	GS30 156	Total GS	CHANGE	GG Mar 390	GG Oct 390	GS Mar 420	GS Oct 360
AGAMIDAE																	
<i>Ctenophorus cristatus</i> (Gray, 1841)			5		5				1	1		2	-1.60	4	1	1	1
<i>Ctenophorus fordii</i> (Storr, 1965)	22	42	15	2	81		6	9	2	2		19	-2.73	19	62	3	16
<i>Ctenophorus reticulatus</i> (Gray, 1845)											1	1	-1.28	1	1	1	
<i>Ctenophorus scrutatus</i> (Sirling and Zietz, 1893)		3	3	7	14				8	8	3	11	+1.23	8	6	6	5
<i>Moloch horridus</i> Gray, 1841		1			2		1	2	1	1		4	+3.12	1	1	4	
<i>Pogona minor</i> (Sternfeld, 1919)	1	1	1	1	7		1	1		3		5	+1.12	2	5	3	2
GEKKONIDAE																	
<i>Diplodactylus gularianensis</i> Storr, 1979			1	2	3		4	8	5	8	4	29	+15.10	1	2	15	14
<i>Diplodactylus naini</i> Kluge, 1962			2	1	3				2			2	+1.04	2	1	1	1
<i>Diplodactylus pulcher</i> (Steindachner, 1870)									1	1	2	3	+4.69	1		2	1
<i>Gehyra purpurascens</i> Storr, 1982			2		2							0	-		1		
<i>Gehyra variegata</i> (Duméril and Bibron, 1836)	1	1	3		6			2	4	6	3	15	+3.90	5	1	3	12
<i>Heteronotia binocri</i> (Gray, 1845)					2							0	-	1	1		
<i>Nephurus lacisimus</i> Mertens, 1958	18	18	2		38		12	9	1	1		23	-1.06	32	6	17	6
<i>Rhynchoedura ornata</i> Günther, 1867		2	2	1	5		1	2	3			6	+1.87	4	1	2	4
<i>Strophurus assimilis</i> (Storr, 1988)					0		3					3	+			3	
<i>Underwoodisaurus milii</i> (Bory, 1825)					0						9	9	+			4	5
PYGOPODIDAE																	
<i>Delma bulteri</i> Storr, 1987	1		1		2							0	-		2		
<i>Pygopus nigricps</i> (Fischer, 1882)				1	1							0	-	1			
SCINCIDAE																	
<i>Cryptoblepharus carnabyi</i> Storr, 1976					3							0	-		3		
<i>Cryptoblepharus plagiocphalus</i> (Cocteau, 1836)			3	1	4			1				1	-2.56	2	2		1
<i>Ctenotus atlas</i> Storr, 1969	4	3	4	1	12		2	3	3	2		10	+1.30	5	7	5	5
<i>Ctenotus brooksi</i> (Loveridge, 1933)	17				17		3					3	-3.63	3	14	1	2
<i>Ctenotus schomburgkii</i> (Peters, 1863)	4	9	5	3	21			1	5	1		7	-1.92	7	14	5	2
<i>Ctenotus uber</i> Storr, 1969				1	7						1	1	-4.48	3	4	1	
<i>Cyclodonorpius melanops</i> (Werner, 1910)			2		2							0	-	1	1		
<i>Egernia depressa</i> (Günther, 1875)				2	10				2	2	2	4	-1.92	4	8	2	2
<i>Egernia formosa</i> Fry, 1914					5							0	-				
<i>Egernia inornata</i> Rosen, 1905	3	2		1	6		2	4	2			8	+2.08	5	1	5	3
<i>Lerisia macropisliopus</i> (Werner, 1903)			1		1		2					2	+3.12		1	1	1
<i>Menetia muelleri</i> (Fischer, 1881)			1	1	3		2				2	4	+2.08	3		2	2
<i>Menetia greyii</i> Gray, 1845	1	2	1	1	6			1	1	1		3	-1.28	3	3		3
<i>Morethia bulleri</i> (Storr, 1963)		1			2							0	-	1	1		
<i>Tiliqua occipitalis</i> (Peters, 1863)					1			1				1	+1.56			1	1



VARANIDAE											
<i>Varanus gouldii</i> (Gray, 1838)	2	2	1	1	1	-1.28	2	1	1	1	
<i>Varanus tristis</i> (Schlegel, 1839)		0			1	+					
ELAPIDAE											
<i>Brachyuropholis fasciolata</i> (Günther, 1872)		0	1						1	1	
<i>Brachyuropholis semifasciata</i> (Günther, 1863)		0	1		1				2	2	
<i>Demansia psammophis</i> (Schlegel, 1837)	2	2							0		
<i>Parasuta monachus</i> (Storr, 1964)	1	1							0	1	
<i>Pseudonaja modesta</i> (Günther, 1872)	3	4							0	2	
<i>Sinosclaps bertholdi</i> (Jan, 1859)	1	0		1					1		1
TYPHILOPIDAE											
<i>Ramphotyphlops australis</i> (Gray, 1845)		0	1	2					3	2	1
<i>Ramphotyphlops bitinctulatus</i> (Peters, 1863)		0		1					1		1
<i>Ramphotyphlops lanatus</i> Storr, 1981		0			1				1		1
MYOBATRACHIDAE											
<i>Neobatrachus</i> sp	1	1							0	1	
<i>Neobatrachus wilsmorei</i> (Parker, 1940)		5							0	5	
DASYURIDAE											
<i>Ningaui ridei</i> Archer, 1975	1	1	5	4	3				12	1	7
<i>Sminthopsis crassicauda</i> (Gould, 1844)	1	1			1				1	1	5
<i>Sminthopsis dolichura</i> Kitchener, Stoddart and Henry, 1984	1	1	1	2	1			12	1	3	16
MURIDAE											
<i>Mus musculus</i> Linnaeus, 1758		0	2	4	1				7		7
<i>Notomys alexis</i> Thomas, 1922	9	14			2				2	8	2
<i>Notomys mitchellii</i> (Ogilby, 1838)	1	1							0	1	
<i>Pseudomys hermannsburgensis</i> (Waite, 1896)	2	2	1	4					5	2	4

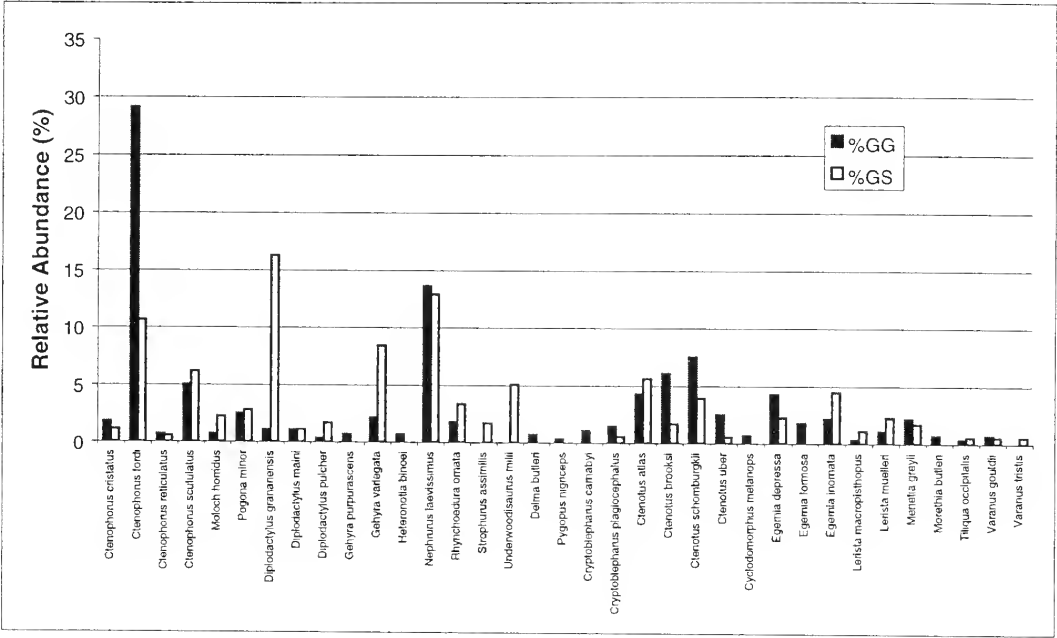


Figure 2 Relative abundance of the lizard assemblages at Goongarrie during the two major surveys undertaken by the Museum (%GG) and CALM (%GS).

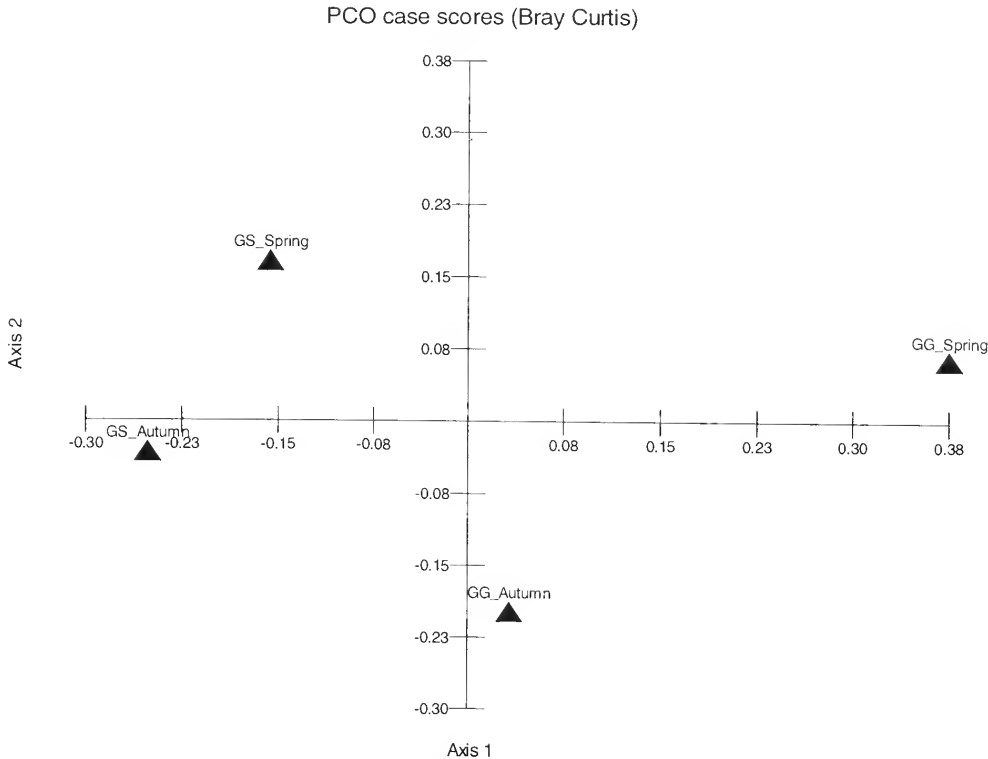
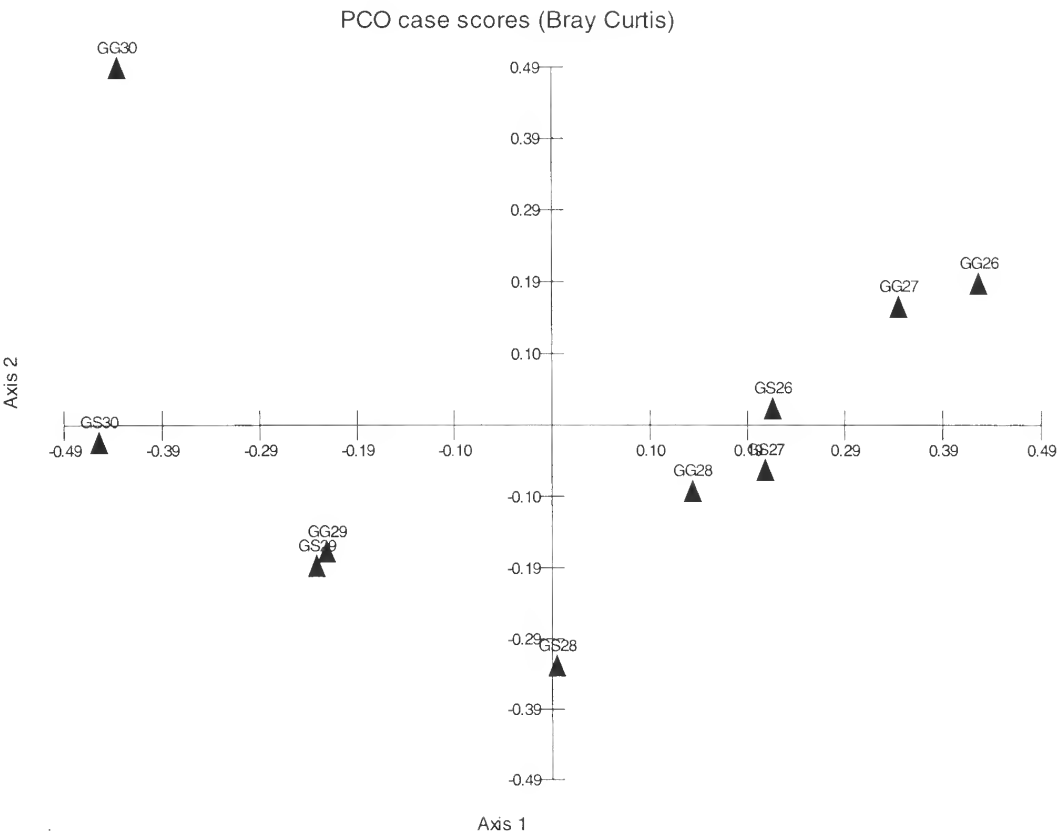


Figure 3 Principal coordinate plot of lizard assemblages on the four sampling periods of the two surveys based on abundance data and Bray-Curtis index of dissimilarity.



**Figure 4** Principal co-ordinates plot of lizard assemblages of the five sampling sites on each of the two surveys, based on abundance data and the Bray-Curtis index of dissimilarity. Key GG26=GS26, GG27=GS27, GG28=GS28, GG29=GS29

while site 29 occurs on calcareous earth and site 30 on clay loam.

**Species Preferences**

The absence of frogs in the CALM sampling periods is probably attributable to the lack of any significant rainfall immediately prior to or during those samplings. However, some minor precipitation on one evening during October 2001 did allow activity by fossorial snakes of the genera *Ramphotyphlops* and *Vermicella* (Table 1). No species of snake was common to both surveys.

The relatively high dissimilarity between sites in their lizard species assemblages (Figure 4) indicates that there are species with defined habitat

preferences that are abundant on some sites and absent from others (see also Table 1). Ignoring species that are represented by a single or very few records, two sites have species that were not recorded on adjacent or other nearby sites. Site 26 has the only records of *Strophurus assimilis* and *Ctenotus brooksi*, while site 30 has the only or the great majority of records of *Ctenophorus reticulatus*, *Underwoodisaurus milii*, *Cryptoblepharus carnabyi*, *Ctenotus uber* and *Egernia formosa*. Some other species (*Ctenophorus cristatus*, *C. fordii*, *Diplodactylus granariensis*, *Cryptoblepharus plagiocephalus*, *Ctenotus atlas*, *C. schomburgkii*, *E. inornata* etc.) occurred in abundance on the sands and sandy loams of sites 26–29 but were not recorded on the clay loams of

**Table 2** Matrix of survey relationships of the lizard faunas based on Bray-Curtis of dissimilarity.

	GG_Autumn	GG_Spring	GS_Autumn	GS_Spring
GG_Autumn	0			
GG_Spring	0.468	0		
GS_Autumn	0.419	0.65	0	
GS_Spring	0.417	0.577	0.348	0

**Table 3** Matrix of sampling site relationships of the lizard faunas based on Bray-Curtis of dissimilarity.

	GG26	GG27	GG28	GG29	GG30	GS26	GS27	GS28	GS29	GS30
GG26	0									
GG27	0.338	0								
GG28	0.54	0.525	0							
GG29	0.82	0.77	0.61	0						
GG30	0.946	0.919	0.892	0.791	0					
GS26	0.532	0.597	0.677	0.731	0.923	0				
GS27	0.509	0.543	0.563	0.714	0.901	0.383	0			
GS28	0.723	0.702	0.494	0.544	0.941	0.647	0.521	0		
GS29	0.839	0.76	0.617	0.471	0.747	0.696	0.537	0.449	0	
GS30	0.98	0.929	0.805	0.679	0.761	0.821	0.829	0.754	0.618	0

site 30. These habitat specialists account for the low similarity between sites on these two types of soil types (Figure 4).

Major increases in the relative abundance of several species (*Diplodactylus granariensis*, *D. pulcher*, *Gehyra variegata*, *Underwoodisaurus milii*) occurred between the two surveys, while others showed marked decreases (*Ctenotus uber*, *C. brooksi*, *Ctenophorus fordii*). These changes contribute substantially to the differences noted in the similarity between different decades.

Amongst the mammals *Mus musculus*, *Sminthopsis dolichura* and *Ningauia ridei* were more abundant on the CALM survey while *Notomys alexis* was more frequently encountered on the Museum survey (Table 1). A great number of juvenile *S. dolichura* was the captured on GS30 on the March 2002 sampling.

## DISCUSSION

More than twenty years after the initial vertebrate survey of five diverse sites in the Eastern Goldfields, a new survey has shown major changes have occurred in both composition and abundance of ground vertebrate species. The re-sampling of five Museum sites near Comet Vale by CALM during October 2001 and March 2002 added nine species (three lizards and six snakes) of ground vertebrates to the known fauna. The herpetofauna recorded from the five sites now totals two species of amphibians and 44 reptile taxa. No new species of mammals were recorded during the CALM survey, with seven small mammal species comprising the known assemblage.

The majority of the six additional species of snake recorded on the CALM survey were attributed to trapping during an evening of precipitation (Cowan personal observation) suggesting that numerous additional species may be expected when sampling continues and incorporates changed seasons and weather conditions. Also, many wideranging species of lizards [eg *Lialis burtonis* *Tiliqua rugosa*] that have distributions encompassing the Goongarrie area (Storr *et al.*, 1983, 1990, 1999, 2002) should be recorded with additional sampling.

The Museum sampling sites were established at the edge of the transition between the more mesic vegetation types and landforms of southwestern Western Australia and those of the arid desert regions (Dell *et al.* 1988). Less than 5 km east of the five sampling sites reported in this study are several additional Museum sampling sites that have recorded the most south-westerly records of *Strophurus wellingtonae*, *S. strophurus*, *Lerista picturata*, *Varanus caudolineatus* and *V. giganteus*. Some of these species are replaced by their ecological homologues on the study sites [*S. wellingtonae* by *Strophurus assimilis* and *L. picturata* by *Lerista macropisthopus*] but the other species could potentially be recorded on the five sites under consideration. When additional information is included from Dell *et al.* (1988) three frogs, 11 snakes and 43 lizards have been recorded from an area that extends over just 11 km but which spans the boundary of two major bioregions.

The mammal assemblages of the five sampling sites were not changed by the CALM survey. However, Cowan (unpublished) and Thompson and Thompson (2002) have shown that up to seven additional species occur nearby and these could be captured with additional trapping effort. These are *Antechinomys laniger*, *Ningauia yvonneae*, *Pseudantechinus woolleyae*, *S. hirtipes*, *Cercartetus concinnus*, *Pseudomys albocinereus*, and *P. bolami*.

As well as the additional reptile species recorded during 2001–2002, some significant changes to species relative abundances were noted (Table 1 and Figure 2). None of the nine species of snakes recorded from the five sampling sites were captured on both surveys. This supports the characteristic pattern of snake captures that have been noted elsewhere (How, 1998) in that they are infrequently captured and usually in low numbers. Only the lizard species were considered in an analysis of changes in relative abundances.

Comparison of lizard species between samplings 20 years apart showed that 19 species decreased in relative abundance while 16 increased (Table 1). The dragon, *Ctenophorus fordii*, and the skinks, *Cryptoblepharus plagiocephalus*, *Ctenotus brooksi*, *C. uber*, *Egernia depressa*, were relatively more

abundant on sites during the 1979–80 survey, while *Moloch horridus*, the geckos *Diplodactylus granariensis*, *D. pulcher*, *Gehyra variegata* and the skink, *Lerista macropisthopus*, had much greater relative abundances on the 2001–02 survey (Figure 2). These changes in relative abundances between surveys reflected, constantly, in changes of relative abundances on the same sites between surveys as well (Table 1).

In his classic study of desert reptiles, Pianka (1996) reported the average magnitude of change in relative abundance of 26 lizards in the decade between 1967–1978 was  $2.70 \pm 1.55$ , while for 31 lizards on the same site between 1978–1990 the average change was  $3.01 \pm 3.46$ . Using the same method of calculation, our data show that the average magnitude of change at Goongarrie for 24 lizards over a 20 year period was  $2.74 \pm 2.84$ . The majority (62.5%) of the 24 species had changes in relative abundance of less than 2.5 times between surveys (Table 1). James (1994) showed that lizard assemblages were highly variable during his three and a half year study and changed in patterns similar to those reported by Pianka (1986) in the Great Victoria Desert, but that this stochasticity was highly seasonal and occurred over small areas.

Pianka (1986) examined shifts in microhabitat and dietary niche as well as changes in relative abundance over 10 year intervals and concluded that the changes in niche parameters and relative abundance were not correlated, suggesting a large amount of stochasticity in the assemblage structure and function. Our data indicate that long-lived species, particularly geckos, show the greatest change in relative abundance over the 20-year time interval. These changes are not correlated with any habitat changes as evidenced by the lack of fire or alteration due to grazing intensity. Changes in the relative abundances of uncommon species are probably artifacts of small sample size and may not have real biological significance.

How and Dell (2000) showed that the mean similarity of lizard assemblages sampled on the same bushland remnants on successive years was 77%. The total lizard assemblage in this study showed that only 24 of the 35 (68.6%) lizard species recorded were common to both surveys. The two Museum surveys were 75% similar while the two CALM surveys were 67% similar based on species occurrence. When abundance data were evaluated using the Bray-Curtis index, the pattern of similarity is reversed with the two CALM surveys being least different and the two Museum surveys most different (Table 2). The four sampling periods encompassed only 25 sampling days at each site, considerably less than the 75 days suggested by How (1998) as being necessary to record 80 percent of the lizard assemblages on sites in the Swan Coastal Plain. James (1994) recorded 32 of 39 (82%)

lizard species within the first 25 days of sampling at Ewaninga, central Australia, however the last 3 species recorded were trapped only between days 160 and 180 of sampling. The addition of previously unrecorded species to the assemblages at Goongarrie during all sampling periods and at all sites (Figure 1) strongly supports this contention of an incomplete documentation.

The high diversity of ground vertebrates at Goongarrie is probably explained by the juxtaposition of differing soil and habitat types in a study area traversing a major biogeographic interface (Dell *et al.*, 1988). Marked changes in habitat and soils over a small distance would also account for the high turnover in lizard species between sites shown during this study.

Consideration of assemblages on the basis of species presence, alone, has been questioned by Balmer (2002) who concluded, “that analyses that do not include species’ relative abundances do not reveal the real ecological patterns in the data”. Our data examining differences in lizard assemblages using abundance data for both between sampling periods (Figure 3) and sites (Figure 4) indicate that ‘real’ changes have occurred in lizard assemblages between surveys 20 years apart.

This study also lends support to the findings of Thompson and Thompson (2002) and How (1998), who evaluated the significance of sampling regime bringing into question the ability of short-term surveys to adequately determine vertebrate assemblages for environmental impact assessments. If the objective of surveys is to document levels of biodiversity to be able to detect future change in relation to changed management criteria, then short-duration surveys of species present do not provide appropriate information. If threatened or rare species are to be the focus of management decisions then short-term surveys infrequently encounter such species and therefore provide little information to assist managers. This study suggests that significant longer-term changes occur in assemblages that cannot easily be detected by shorter but more intensive sampling regimes and it also indicates that changes in assemblage structure are better able to be evaluated using abundance data.

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## A new genus and species of hermit crab (Crustacea: Anomura: Paguroidea) from northwestern Australia

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**Abstract** – A new genus and new species of the hermit crab family Paguridae are described and illustrated from specimens collected off northwestern Australia. The genus, *Cycetopagurus*, gen. nov., is distinguished by a combination of characters shared individually with several genera that are collectively recognized by the development in males of an elongate right and a short left sexual tube, and the presence in females of paired and modified first pleopods. However, the armature of the telson of the type species, *Cycetopagurus morgani* sp. nov., of the new genus that consists of corneous spines is reminiscent of the family Parapaguridae.

### INTRODUCTION

Among the materials still on loan to the late Mme Michèle de Saint Laurent, Muséum national d'Histoire naturelle, Paris, were eight specimens of a new genus and species from the collections of the Western Australian Museum. Although recognized by de Saint Laurent, these taxa were still unreported at the time of her death. This material now has been entrusted to the author for formal description.

Some of the specimens are poorly calcified, and the majority of appendages are disarticulated. The specimen selected as the holotype does have three ambulatory legs still attached to the cephalothorax, and the abdomen is only slightly damaged. It has been possible to determine, with reasonable confidence, which of the detached chelipeds and remaining pereopod belong to the holotype. Despite the relatively poor condition of the remaining specimens, all are considered paratypes, as the distinctive characters of these bodies and appendages confirm their conspecificity. The genus adds yet another piece to the evolutionary puzzle of pagurid genera that have developed male sexual tubes. All specimens have been returned to the Western Australian Museum (WAM).

### TERMINOLOGY

Gill structure is interpreted according to the definition of Lemaitre (2004); the criterion for sexual tube length is that proposed by McLaughlin (2003a). All other terminology for the diagnosis and description follows that of McLaughlin (2003b). The shield length (sl), as measured from the tip of the rostrum to the midpoint of the posterior margin of

the shield is an indication of animal size; however, as is the case in a few paguroid genera, shield width increases disproportionately to length in the type species, rendering the shield length less informative than would be expected. The ratio of corneal diameter to length of the ocular peduncle has been obtained by measuring the length of the left ultimate peduncular segment, including the cornea, along the lateral surface; corneal diameter is the maximum measured dorsal width of the left cornea. The abbreviations stn and ovig. are used for station and ovigerous, respectively.

### SYSTEMATICS

#### Family Paguridae Latreille, 1802

#### *Cycetopagurus* gen. nov.

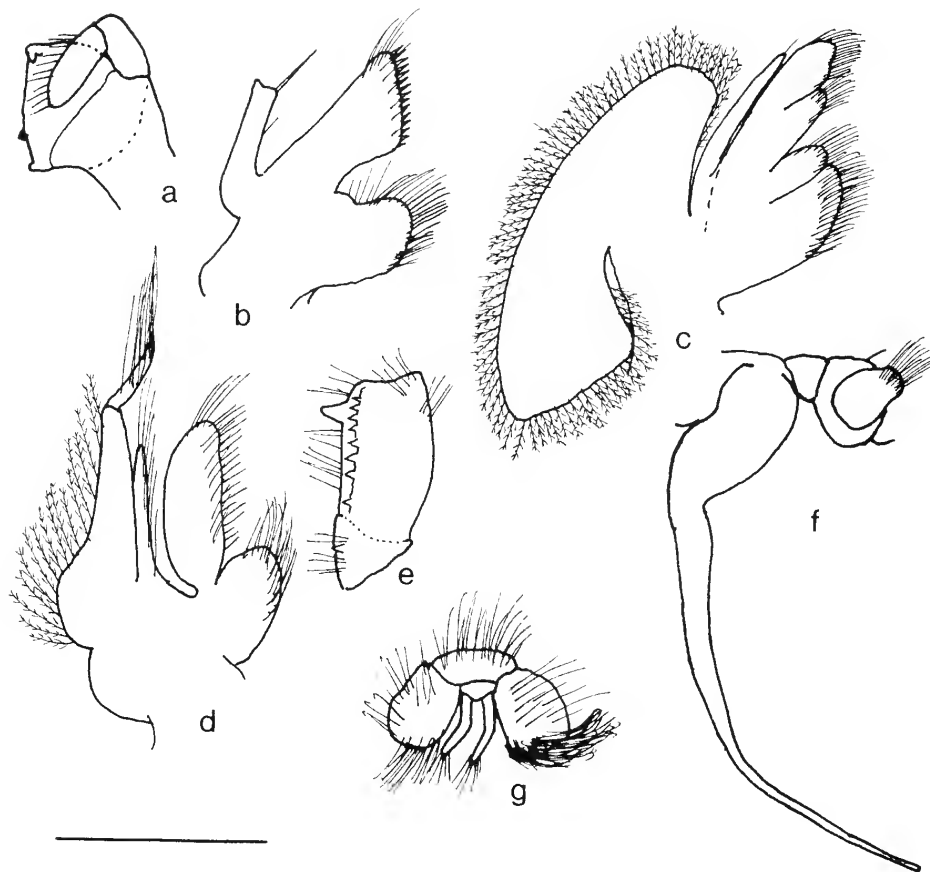
#### Figure 1

#### Type species

*Cycetopagurus morgani* sp. nov., gender masculine.

#### Diagnosis

Eleven pairs of biserial phyllobranchiate gills. Rostrum well developed, broadly triangular. Ocular acicles subrectangular to subovate. Antennal peduncle with supernumerary segmentation. Mandible (Figure 1a) with corneous tooth and 1 to few calcareous denticles on incisor inner margin. Maxillule (Figure 1b) with external lobe of endopod weakly developed, not recurved. Maxillule (Figure 1c) with elongate, slender endopod overreaching distal margin of scaphognathite. First maxilliped (Figure 1d) with basally swollen, distally slender exopod. Second maxilliped without distinguishing



**Figure 1** *Cycetopagurus morgani*, gen. nov., sp. nov., a–e, g, female paratype (sl = 3.2 mm) WAM C33803, f, male holotype (sl = 3.0 mm) WAM C33802; a, mandible (right, internal view); b, maxillule (right, external view); c, maxilla (right, external view); d, first maxilliped (right, external view); e, basis-ischium of third maxilliped (right, internal view); f, coxae of fifth pereopods; g, coxae of fifth pereopods and paired first pleopods. Scale bar equals 1.0 mm (a–e) and 2.0 mm (f, g).

characters. Third maxilliped with crista dentata somewhat reduced (Figure 1e), but with prominent accessory tooth.

Chelipeds elongate, subequal, right stouter, but often shorter. Sternal plate of third pereopods broad, median hinge narrow. Fourth pereopods semichelate; with single row of spiniform, corneous scales in propodal rasp; dactyl without preungual process.

Coxae of fifth pereopods in males asymmetrical, right with long sexual tube (Figure 1f) directed posteriorly and externally, stout proximally, elongate and extremely filiform distally; left with very short, stout sexual tube; unequally biramous, unpaired, markedly reduced left pleopods 3–5. Females with paired gonopores, paired and modified first pleopods (Figure 1g), and unpaired left pleopods 2–5.

Telson with weak transverse indentations

separating anterior and posterior portions; anterior lobes each with marginal spiniform bristles; rounded posterior lobes separated by distinct median cleft, terminal and lateral margins armed with corneous spinules.

#### **Etymology**

From the Greek *kyketes* meaning mixer, and *paguros* meaning crab. The name is chosen to reflect the combination of diagnostic characters that this genus shares with several other paguroid genera.

#### **Remarks**

In the development of the very elongate and terminally filiform right male sexual tube directed posteriorly and toward the exterior, *Cycetopagurus* gen. nov. is quite similar to *Nematopaguroides* Forest and de Saint Laurent, and *Pseudopagurodes*



McLaughlin. However, in the latter two genera the rostrum is reduced or broadly rounded. But more importantly, females of the both genera lack paired and modified first pleopods, while females of *Cycetopagurus* are provided with them as are females of *Nematopagurus* A. Milne-Edwards and Bouvier, *Michelopagurus* McLaughlin and several other pagurid genera. The development of a corneous tooth and one or more calcareous denticles on the incisor process of the mandible is a character *Cycetopagurus* shares with *Bythiopagurus* McLaughlin, although the calcareous denticles are developed on the inner incisor margin in *Cycetopagurus* and on the upper incisor margin in *Bythiopagurus*. The elongation of the left cheliped in *Cycetopagurus morgani*, sp. nov., with the tendency of the fingers to curve ventrally is reminiscent of left cheliped development in *Catapagurus franklinae* McLaughlin, 2004. In both species, the length of the left cheliped occasionally exceeds that of the right, although the latter is always stouter.

By far the greatest number of shared characters is seen between *Cycetopagurus*, gen. nov., and the also monotypic genus, *Icelopagurus* McLaughlin. Both type species have short, stout ocular peduncles and well developed rostra. In both species the crista dentata of the third maxilliped is somewhat reduced, but the accessory tooth is prominent; the sternites of the third pereopods are broad and plate-like. Males of both genera have moderate to long right sexual tubes and very short left tubes. The most significant shared character is seen in the armature of the telson, which consists of a row of corneous spines on each terminal margin. Corneous telsonal spines are common in the Parapaguridae (e.g., Lemaitre, 1994, 1996, 1999), but in the Paguridae such spines are reported only for *Icelopagurus* and now *Cycetopagurus*. However, in *I. crosnieri* McLaughlin, 1997, these spines are long, few in number, and do not extend onto the lateral margins of the posterior lobes. In contrast, the spines in *C. morgani*, sp. nov., are short, numerous, and extend the full lengths of the terminal and lateral margins. Despite these similarities, the two taxa are readily distinguished. The ocular acicles of *I. crosnieri* are elongate and slender, as are the dactyls and propodi of the ambulatory legs; the right male sexual tube is not terminally filiform, and females lack paired and modified first pleopods. As the following description of *C. morgani* indicates, the ocular acicles of this species are subrectangular or subovate and not particularly long; the dactyls and propodi of the ambulatory legs are not notably elongate; the right male sexual tube is terminally filiform, and females have paired and modified first pleopods. Additionally, the lateral and mesial faces of the carpi of both chelipeds, at least in males of *C. morgani*, are ornamented with few to numerous capsulate setae

### *Cycetopagurus morgani* sp. nov.

Figures 1, 2

#### Type locality

NW of Carnarvon, off Cape Cuvier, Western Australia, 24°04'S, 112°52'E.

#### Holotype

♂ (sl = 3.0 mm) (WAM C33802), CSIRO stn Dm 6/192/63, 24°04'S, 112°52'E, 140 m, 8 October 1963.

#### Paratypes

2 ♂ (sl = 2.8, 2.9 mm), 2 ovig. ♀ (sl = 3.0, 3.2 mm) (WAM C33803), CSIRO stn Dm 6/192/63, 24°04'S, 112°52'E, 140 m, 8 October 1963.

3 ♂? (sl = 2.4–3.0 mm) (WAM C33804), CSIRO stn Dm/187/63, 23°39'S, 113°12'E, 134m, 7 October 1963.

#### Description

Shield (Figure 2a) as long as broad or slightly broader, weakly to moderately well calcified, slightly vaulted; anterior margin between rostrum and lateral projections nearly straight to weakly concave; anterolateral margins sloping; posterior margin truncate; dorsal surface with scattered short setae. Rostrum prominently produced, broadly triangular, terminally subacute, reaching to midlength of ocular acicles. Lateral projections obsolete or nearly so, unarmed or each with minute spinule. Carapace lateral lobes narrow to moderately broad, weakly to moderately well calcified. Posterior carapace median plate membranous or weakly calcified anteriorly, membranous posteriorly; posterior carapace lateral plates usually weakly calcified for almost entire length; cardiac sulci and sulci cardiobranchialis extending nearly to posterior carapace margin.

Ocular peduncles short and stout, 0.3–0.5 length of shield; corneas prominently dilated, corneal diameter 0.6–0.8 of peduncular length. Ocular acicles subrectangular to subovate, terminating bluntly or subacutely, but each with distinct submarginal spine; separated basally by breadth of rostrum.

Antennular peduncles, when fully extended, overreaching ocular peduncles by slightly less to slightly more than entire lengths of ultimate peduncular segments. Ultimate segment with 1–4 long, simple setae on dorsal surface distally. Penultimate segment with occasional, short setae. Basal segment with spine on dorsolateral margin.

Antennal peduncles, when fully extended, overreaching ocular peduncles by at least 0.2 lengths of penultimate segments. Fifth and fourth segments with few scattered setae. Third segment with tufts of setae on ventrodistal margin, and sometimes also very small spinule. Second segment with dorsolateral distal angle produced,

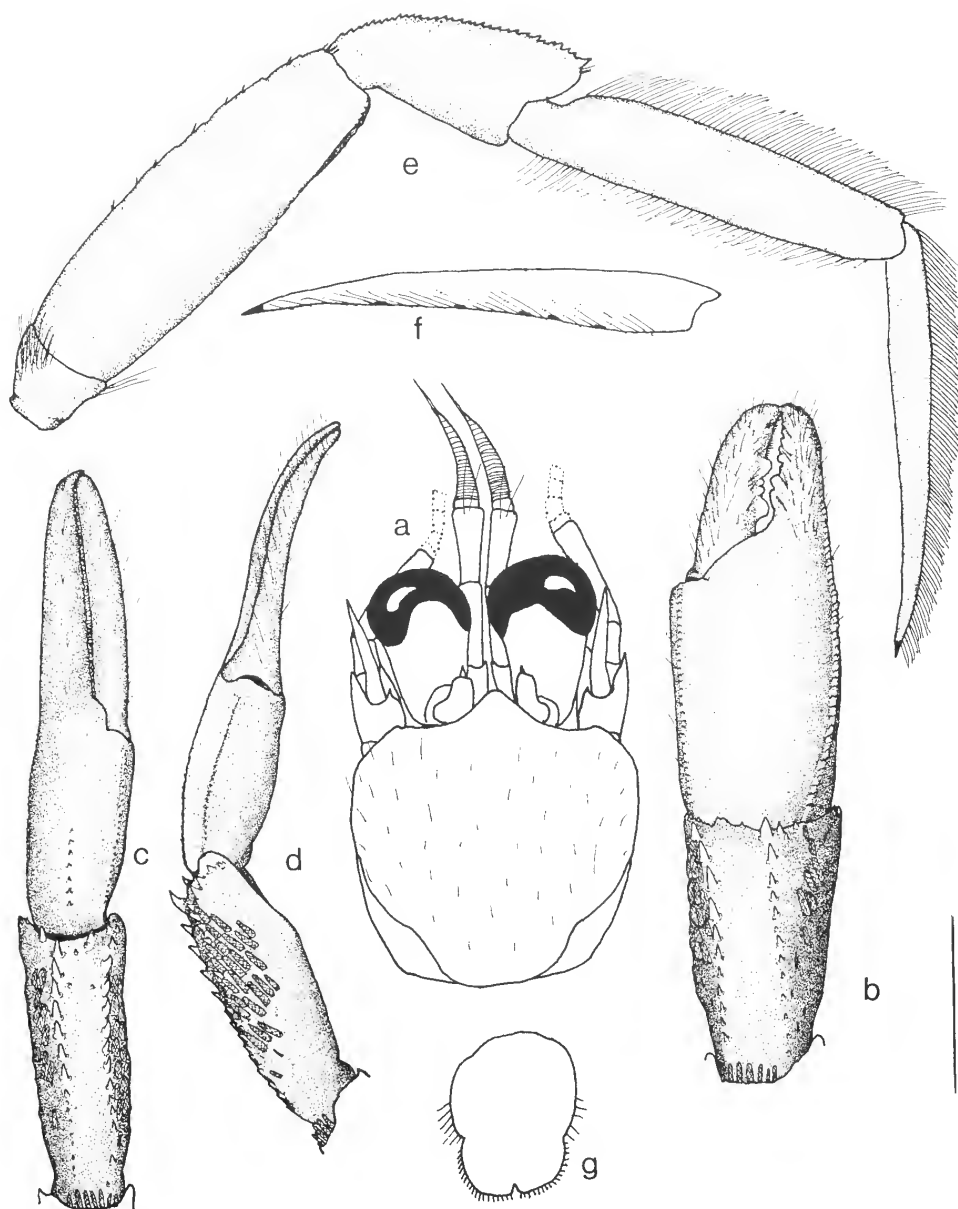


Figure 2 *Cycetopagurus morgani*, gen. nov., sp. nov., male holotype WAM C33802: a, shield and cephalic appendages (aesthetascs omitted); b, chela and carpus of right cheliped (dorsal view); c, chela and carpus of left cheliped (dorsal view); d, chela and carpus of left cheliped (mesial view); e, right second pereopod (lateral view); f, dactyl of right second pereopod (mesial view); g, telson. Cross-hatched setae represent capsulate setae. Scale bar equals 1.0 mm (g) and 2.0 mm (a-f).

terminating in simple spine; dorsomesial distal angle with well developed spine. First segment unarmed. Antennal acicle reaching beyond distal margin of fourth peduncular segment; terminating in acute spine; mesial margin with few moderately long setae. Antennal flagellum (missing in holotype

and most paratypes) long but usually not longer than ambulatory legs, naked or with very few short setae on proximal articles. Sternite of third maxillipeds with median concavity, unarmed.

Chelipeds subequal; right stouter, but often slightly shorter than left. Right cheliped (Figure 2b)

with dactyl 0.7–0.8 length of palm; dorsomesial margin rounded, unarmed but with row of sparse, thin setae, dorsal surface with scattered, moderately short setae; ventral surface also with few tufts of setae; proximal half of cutting edge with 1 or 2 prominent calcareous teeth, frequently separated by 1 or 2 smaller calcareous teeth, distal half with row of small corneous teeth, terminating in small corneous claw. Palm somewhat dorsoventrally swollen; slightly shorter to approximately equal to length of carpus; dorsomesial and dorsolateral margins each with row of very small granules or tubercles, dorsal surface convex, unarmed or with short row of tiny granules or spinules in midline proximally, and scattered short, thin setae; rounded mesial, lateral and ventral surfaces each with few scattered short, fine setae. Cutting edge of fixed finger with 2 or 3 large calcareous teeth proximally and row of small calcareous teeth distally, terminating in small calcareous claw. Carpus with row of moderately small, acute spines on dorsomesial margin, 1 or 2 small spines mesially on distal margin, second row of spines beginning at dorsolateral margin proximally but becoming median at distal margin, dorsal surface laterad of median spine-row sloping laterally, dorsolateral margin not delimited; mesial and lateral surfaces each with few individual capsulate setae to several short, transverse rows of closely-spaced, capsulate setae; ventromesial and ventrolateral margins rounded, ventral surface minutely granular or spinulose. Merus with row of capsulate setae on dorsodistal margin and often extending onto mesio- and laterodistal margins; dorsal, lateral and mesial surfaces unarmed but with few scattered, very short, stiff bristles; ventromesial and ventrolateral margins and ventral surface minutely tuberculate or granulate, ventrolateral distal angle with 1–4 tiny spinules. Ischium unarmed.

Left cheliped (Figures 2c, d) with long, slender dactyl and fixed finger, frequently curving ventrally, with or without hiatus; margins of neither dactyl nor fixed finger delimited, rounded surfaces unarmed but with numerous short, thin setae, often forming sparse longitudinal row on mesial face of dactyl; cutting edges each with row of small, corneous teeth. Palm equal to or slightly shorter than carpus; dorsomesial and dorsolateral margins each with row of very small granules or tubercles, latter not extending onto fixed finger, dorsal surface weakly convex, dorsal midline with short row of tiny spines or spinules, at least in proximal half; ventral surface with scattered, moderately short, fine setae. Carpus with dorsal surface relatively flat, armed with few tiny spines, dorsomesial and dorsolateral margins each with row of small spines, largest laterally; mesial and lateral faces each with either short, coarse bristles or capsulate setae, latter forming short transverse rows in holotype;

ventrolateral distal margin with 1 or 2 small spines in distal half, ventromesial margin with 2–4 tiny spinules or tubercles distally; ventral surface granular or tuberculate. Merus with row of capsulate setae on dorsodistal margin, dorsal surface unarmed but with few short, stiff bristles and few longer thin setae, lateral and ventral surfaces unarmed, ventrolateral and ventromesial margins each with row of very small tubercles or subacute spinules, ventrolateral margin with 1 additional more prominent spine distally; ventral surface tuberculate or granular. Ischium unarmed.

Ambulatory legs (Figures 2e, f) similar from left to right; very little difference in lengths of second and third ischia. Dactyls very slightly shorter to slightly longer than propodi; dorsal surfaces each with row of closely-set, long, moderately stiff setae; mesial faces each very weakly concave; ventral margins each with row of moderately stiff setae (frequently directed upward and not visible in lateral view) and 5–9 rather widely-spaced, very small, corneous spines. Propodi each with 1 dorsal and 1 ventral row of long setae. Carpi each with mixed row of small and very small spines on dorsal surface, dorsodistal spine largest. Meri each with low protuberances and few short, spiniform bristles on dorsal surface; ventral margins each spinulose. Ischia unarmed, but each with tuft of setae on lateral face. Dactyls of fourth pereopods with very short claws. Fifth pereopods chelate.

Sternite of third pereopods broad; anterior lobe narrowly subrectangular, unarmed.

Coxae of fifth pereopods in males with long right sexual tube (Figure 1f), proximal portion stout, curving posteriorly and externally; elongate distal portion tapering and becoming filiform; left sexual tube very short, with terminal tuft of setae. Coxae of fifth pereopods of females (Figure 1g) each with tuft of long setae distally, densest on left; 2-segmented, paired first pleopods each with terminal setae.

Telson (Figure 2g) with prominent median cleft separating rounded posterior lobes; terminal and lateral margins each with row of closely-spaced, small or very small corneous, bristle-like spines.

#### Color

Unknown.

#### Habitat

Unknown

#### Distribution

Known only from northwestern Australia, off Cape Cuvier and North West Cape; 134–140 m.

#### Etymology

This species is named for Dr. Gary J. Morgan,

former curator of Crustacea and now executive director of the Western Australian Museum, in recognition of his major contributions both to paguroid systematics and the growth and success of the museum.

### Variation

Because of the conditions of the paratypes, it has not been possible to adequately assess potential sexual dimorphism. However, of the four paratypes from station Dm6/192/63, two are ovigerous females and two are males. While there is only one right cheliped among their appendages, there are three left. One, presumably belonging to one of the males, agrees with the male holotype in having an elongate and ventrally curved dactyl and fixed finger; the mesial and lateral faces of the carpus each have several short, transverse rows of capsulate setae. The dactyls and fixed fingers of remaining two left chelipeds are shorter and are not curved; the lateral and mesial faces of the carpi have scattered short, stiff, bristle-like setae, but lack capsulate setae. Despite the 0.4 mm difference in shield lengths between the smallest male and largest female, all four specimens vary little in actual size, because shield width more than length seems to increase with growth. Although the differences observed among the four left chelipeds may represent sexual dimorphism, both in the lengthening and curvature of the dactyl and fixed finger and in the development of capsulate setae on the carpus in *C. morgani*, sp. nov., this cannot be ascertained from the limited material presently available. A similar elongation of the left cheliped was found to represent allometric growth rather than sexual dimorphism in *Bythiopagurus macrocolus* McLaughlin, 2003b.

Specialized capsulate structures are known to develop on the spines of the chelipeds in *Nematopagurus spinulosensoris* McLaughlin and Brock, 1974, and seemingly similar structures have been reported on the spines and/or tubercles in a few species of *Pagurus* (cf. McLaughlin, 1997). Simple capsulate setae are known to develop on the third through fifth sternites in several genera (cf. McLaughlin, 1981). The presence of what appear to be capsulate setae on the lateral and mesial faces of the carpi of the chelipeds is described for the first time in *C. morgani*, sp. nov. Unfortunately, the paucity and poor condition of these chelipeds precluded any detailed examination of the capsulate structures; however, their development appeared to be growth related. Very limited observations suggested that stiff bristle-like structures in particular positions on one individual had developed into capsulate setae in the same position on a second specimen.

### Affinities

As indicated previously, *Cycetopagurus* gen. nov., and its type species, *C. morgani*, sp. nov., share characters with several other genera and species of the Paguridae. However, neither the genus, nor the species can be considered closely related to any specific taxa. In addition to the similarities mentioned at the generic level, the ambulatory dactyls and propodi of *C. morgani*, with their fringes of long setae, are suggestive of species of *Spiropagurus* Stimpson, whereas the armature of the carpi is reminiscent of species of *Catapagurus* A. Milne-Edwards. *Cycetopagurus morgani* is immediately distinguished from all known species by the armature of the telson. However, in the absence of the telson, the suite of characters that define this taxon, when taken collectively, assure its recognition.

### DISCUSSION

Of the 69 genera of the Paguridae reviewed by McLaughlin (2003a), males of 35 genera were characterized as developing of one or a pair of sexual tubes, and at least some species in an additional six genera showed evidence of papillae or very short protuberances of the vas deferens from one or both coxae. *Cycetopagurus*, gen. nov., is one of 18 genera in which at least some species develop paired sexual tubes, with the right as long as or longer than the left. Although the right sexual tube can be categorized as long (> 5 coxal lengths) in nine of these genera, it is terminally filamentous in just four, including *Cycetopagurus*. Extensions of the vas deferens into penes or sexual tubes occur in both brachyuran and paguroid crabs but appear to represent different evolutionary mechanisms. The brachyuran penes function in association with the male paired first and second pleopods, sexually modified for sperm transfer (Guinot and Tavares, 2003). No paired and sexually modified male pleopods are present in paguroid taxa in which sexual tubes develop. Whether these tubes in pagurids function in sperm transfer has not been documented in living animals. However, de Saint Laurent (1968), García-Gómez (1988) and Tudge and Lemaitre (in press) have recorded the presence of spermatophores in the sexual tubes of *Decaphyllus junquai* de Saint Laurent, 1968, *Emneobranthus flavioculatus* García-Gómez, 1988, and *Micropagurus acantholepis* (Stimpson, 1858), respectively.

Hazlett (1968), reporting on observed copulations in *Anapagurus chiroacanthus* (Lilljeborg, 1856) and *A. breviaculeatus* Fenizia, 1937, stated that the mating pairs were "in very close contact, genital orifices touching in copula." Hazlett (1968) noted that in contrast to species of *Pagurus* Fabricius, males of *Anapagurus* Henderson species each had a "tubular

projection" of the vas deferens on the coxa of the fifth pereopod. Hazlett concluded that internal fertilization seemed especially possible from the observed behavior "– genital contact *in copula*" in species of *Anapagurus*. However, Guinot and Tavares (2003), quoting personal communication from Lemaitre and Tudge, suggested that insemination in hermit crabs was external because spermatophores had been observed attached to various parts of the [female] bodies in species with male sexual tubes.

Tudge and Lemaitre (in press), in the first study of the micro- and ultrastructure of a pagurid sexual tube, examined the sexual tube of *M. acantholepis* and refuted the earlier hypotheses that the pagurid sexual tube was a simple extension of the vas deferens (Henderson, 1888; Alcock, 1905; Fenizia, 1937). Tudge and Lemaitre (in press) found that while the tube of *M. acantholepis* was a functional extension of the vas deferens, it was encased in a structural elongation of the coxal segment. They also suggested that the terminal opening of the tube was capable of considerable expansion to allow the preformed, tripartite spermatophore (Tudge, 1999) to exit.

The sexual tubes of males of *Decapophyllus*, *Enneobranchius*, *Micropagurus*, and *Anapagurus*, while narrower terminally than basally, are unquestionably not filiform, thus expansion to permit spermatophore discharge would certainly be feasible. However, in *Nematopaguroides*, *Cycetopagurus*, gen. nov., and similar genera, dilation of such a slender tube over considerable length seems improbable. De Saint Laurent-Dechancé (1966) reported dimorphism in spermatophores in the paired sexual tubes of species of *Iridopagurus* de Saint Laurent-Dechancé. It might also be possible that the sexual tubes themselves, when paired, serve different functions for the male. In the sessile barnacle, *Semibalanus balanoides* (Linnaeus, 1767), for example, the penis of a functional male has two roles. Prior to copulation and insemination, the penis reportedly "searches" and "tests" the substrate for a functional female (Barnes and Barnes, 1956; Barnes *et al.*, 1977). It is conceivable that the rather whip-like sexual tube characteristic of species in genera such as *Cycetopagurus* serves a function as yet undetermined, whereas the shorter tube participates in actual spermatophore transfer.

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## A new species of *Australomedusa* (Cnidaria: Hydrozoa: Anthomedusae) from a saline lake in south-western Western Australia

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**Abstract** – *Australomedusa thrombolites* sp. nov. is described from Lake Clifton, Yalgorup National Park. It is a small medusa with a bell height (BH) of about 1.5 mm. It differs from its only other congener, *A. baylii*, primarily in the shape and location of the gonads, and in having only 3–5 tentacles per cluster (verses 5–9). Furthermore, in preserved specimens, the tentacle length is relatively longer, about 75% BH, though this character tends to be highly variable in most medusa species.

### INTRODUCTION

Very little is known of the non-marine medusan fauna of Australia. Despite extensive surveys of non-marine aquatic habitats by various researchers, medusae are rarely encountered. We suspect that this is partly due to the delicate nature of medusae, which often do not survive collecting techniques used for other taxa, but we also suspect that non-marine medusae are genuinely rare in Australia.

Only two genera have thus far been recorded from Australian waters, the freshwater cosmopolitan genus, *Craspedacusta*, and the salt lake genus, *Australomedusa*. *Craspedacusta* tends to inhabit artificial lakes and ponds and has been recorded from all states except Tasmania and the Northern Territory. *Australomedusa* has only been recorded three times, firstly from south-eastern South Australia, just south of Robe (Russell 1970), secondly from the central coast of Victoria, near Inverloch (Russell 1971, Bayly 1973) and thirdly from a true estuarine system (the Werribee) west of Melbourne, Victoria (Neale and Bayly 1974). Only one species, *A. baylii*, is currently recognized.

In this paper we describe a new species, collected from Lake Clifton, a moderately saline lake in Yalgorup National Park, south-western Western Australia.

### MATERIALS AND METHODS

Specimens were collected using a hand held 500 µm mesh plankton net from among, and over, thrombolites in about 1m of water in Lake Clifton, Yalgorup National Park, Western Australia. They were relaxed with MgCl and preserved in 10% for maldehyde/propylene glycol solution.

Salinity was measured using an ICI 302 conductivity meter.

Sexes were determined as follows: gravid females were identified by the presence of spherical eggs or lumpy gonads. Mature males were identified on the basis of full gonads, which were smooth rather than lumpy. All specimens that could not be positively identified as mature males or gravid females were considered immature, though this category could conceivably include spawned specimens and probably also includes a disproportionate number of males.

The holotype male, allotype female and some paratypes have been deposited in the Western Australian Museum, Perth (WAM). Additional paratypes have been deposited in the South Australian Museum, Adelaide (SAM).

All of the material of *A. baylii* listed by Russell (1970, 1971), including the types, deposited in the Natural History Museum, London, was examined by one of us (L.G.) for comparative purposes.

### SYSTEMATICS

#### Family Australomedusidae Russell, 1970

##### Remarks

When Russell (1970) described *Australomedusa baylii* he characterized the family thus, "in view of the multitentacular character of the marginal bulbs the erection of a new family, the Australomedusidae, would be justified with the diagnostic characters of the type genus *Australomedusa*." However, in his paper describing the females of *A. baylii* (Russell 1971) he reintroduced the family name as new only adding

"the occurrence of only two types of nematocyst indicates that the medusa should be placed in a new family, Australomedusidae, fam. nov.". Clearly the correct citation for the family is Russell 1970; not 1971 as presumed by subsequent authors (e.g. Dumont 1994; Bouillon and Boero 2000).

Genus *Australomedusa* Russell, 1970

*Australomedusa thrombolites* sp. nov.

Figure 1

Material Examined

Holotype

Male (WAM Z13498), Lake Clifton, Yalgorup National Park, south-western WA [32°44.714'S, 115°39.230'E], collected at the thrombolite observation walkway, near 'Cape Bouvard' winery, by W. Zeidler and L. Gershwin, 10 December 2000.

Allotype

Female (WAM Z13499), same collection data as holotype.

Paratypes

11 males, 63 females, 31 juveniles, or specimens of undeterminable sex (SAM H1330); 10 males, 74 females, 31 juveniles, or specimens of undeterminable sex (WAM Z13500); same collection data as holotype.

Diagnosis

*Australomedusa* with 3–5 tentacles per group; with laterally flattened "gonads" in both sexes, approximately 1/3, or less, the distance from the stomach to the margin.

Description of holotype (male)

Body spherical to globular, with a scattering of minute nematocyst warts on the whole exumbrellar surface. Stomach small, quadrate, tapering rapidly to short, narrow, cylindrical manubrium with simple mouth with four lips; attached directly to subumbrellar surface. Main gonads on interradial sides of manubrial wall; smoothly bulging. Lateral gonads small, roundish, flattened out laterally and barely protruding down into subumbrellar space; located on proximal 1/4 or 1/3 of radial canals. Tentacle bulbs four, perradial. Tentacles in clusters of three (only one bulb) or four; narrow and lacking nematocysts proximally, thickened somewhat and densely covered with nematocysts throughout distal 2/3 to 3/4; typically held outward in a fan-like fashion; about 3/4 bell height (BH) in length when preserved. Ocelli, one per tentacle cluster, located at the very distal center of the adaxial side. Radial canals, four, perradial, straight, smooth-

edged, narrow. Ring canal same width as the radial canals. Each quadrant of bell margin typically with a single rudimentary interradial bulb or wart. Velum very wide. Statocysts not observed (lacking?). Color: In life, the body is transparent with a faintly greenish hue to the subumbrella; tentacles are faintly reddish in the outer half; the ocelli are bright red.

Description of allotype (female)

Like holotype, except that the gonads on the interradial walls of the manubrium appear lumpy with eggs. The lateral gonads do not appear to contain eggs. All tentacle bulbs with cluster of four tentacles.

Variation from holotype and allotype

Tentacle number: Variation in the number of tentacles on each marginal bulb is summarized for adult specimens in Table 1. Larger specimens tend to have more tentacles per cluster, but this is not constant; some smaller specimens have four-five, while some larger specimens only have three, and the number per cluster can vary in the same specimen, although it is most often four. Only one specimen had three tentacles on all four clusters and only three specimens had five tentacles on all four clusters. Similarly, the 62 juvenile specimens examined had 3–5 tentacles per cluster, seemingly unrelated to size, although details of tentacle distribution for individual specimens were not recorded.

Tentacle length: This varied from about 0.6x to 0.8x BH.

Table 1 Number of tentacles on marginal bulbs for adult specimens of *Australomedusa thrombolites* sp. nov. examined.

Number of females	Number of tentacles on each marginal bulb			
113	4	4	4	4
3	3	4	4	4
4	3	3	4	4
1	3	3	3	4
1	3	3	3	3
6	5	4	4	4
2	5	5	4	4
5	5	5	5	4
3	5	5	5	5
Number of males				
13	4	4	4	4
4	3	4	4	4
1	3	3	4	4
1	3	3	3	4
2	5	4	4	4
1	5	5	4	4



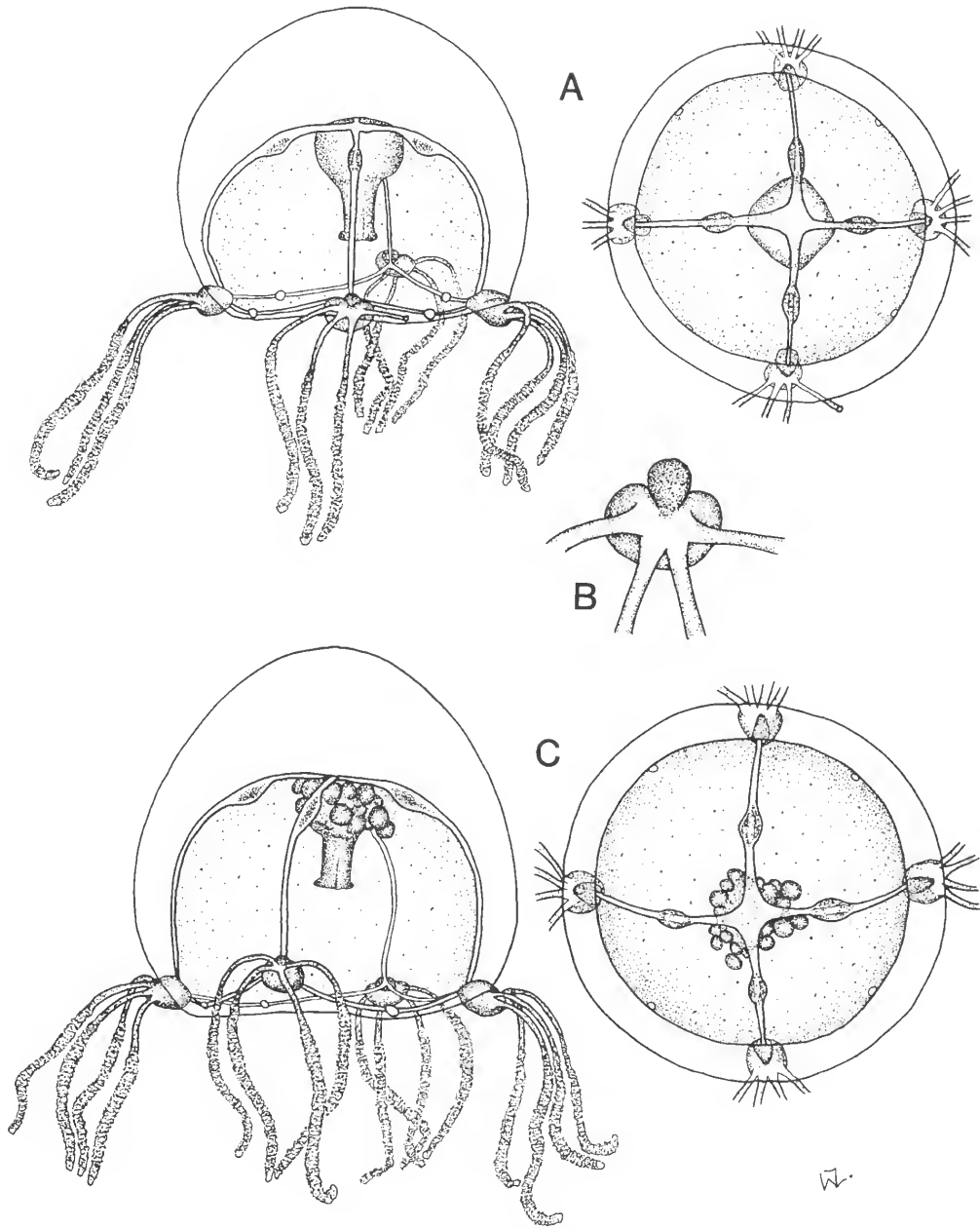


Figure 1 *Australomedusa thrombolites* sp. nov. A. Holotype male, lateral and aboral view. B. Tentacular bulb of holotype. C. Allotype female, lateral and aboral view.

Tentacle thickness: Some specimens have slightly thickened tentacles, particularly those without lateral gonads.

Nematocysts: The proportion of tentacle covered by nematocysts is highly variable, ranging from about the distal 2/3 to about the distal 7/8 but can be almost totally covered in specimens with thickened tentacles.

Presence of lateral gonads: Of the 138 specimens

determined as females and the 22 specimens determined as males, 35 females (26%) and 9 males (41%) were without lateral gonads.

Location of lateral gonads: Never located beyond proximal 1/3 of radial canal but are sometimes very close to the apex in some specimens.

Interradial marginal warts: Most specimens have only one wart per interradius. Some have two, or occasionally three, but never in all of the interradia.

Only one specimen had four, but only in one interradius.

#### Type locality

Lake Clifton, Yalgorup National Park, south-western WA [32°44.714'S, 115°39.23'E]. Salinity at time of collection = 31.5 ppt.

#### Distribution

Only known from the type locality.

#### Etymology

The specific name "*thrombolites*" (pronounced "throm-bo-LITE-eez") is in reference to the dominant life form in the lake, the Lake Clifton Thrombolites.

#### Remarks

This species is similar to *A. baylii* Russell, 1970, but differs in several key characters. First, while the females of *A. thrombolites* have eggs clustered on the manubrium as do the females of *A. baylii*, the former possesses lateral gonads in both sexes, whereas they are lacking in the females of *A. baylii*. Second, the lateral "gonads" are of a different shape and location, being flattened laterally against the subumbrella, and located about 1/3 the distance away from the stomach in *A. thrombolites*, whereas in *A. baylii* they start out adjacent to the stomach and move to the distal half of the radial canal, and they are pouched downward into the subumbrellar cavity. Third, the tentacle number in each cluster is only four (occasionally 3–5) in *A. thrombolites*, but typically six–seven (occasionally 5–9) in *A. baylii*. Tentacle number is independent of body size in both species, and is often unequal on the same specimen. Tentacle length in preserved specimens is about 75% BH for *A. thrombolites*, compared to about 50% BH or less for *A. baylii*. Russell (1971) mentions the occurrence of two types of nematocysts for *A. baylii*, desmonemes and microbasic euryteles. We lacked the facilities to examine the nematocysts of *A. thrombolites* in the field and obtained poor results with preserved material. Thus, comparison of this character will depend on the future examination of living material.

### DISCUSSION

Two factors, which have become evident from the comparison of *A. thrombolites* with *A. baylii*, raise the question of whether the South Australian and Victorian populations of *A. baylii* are indeed the same species. First, the two populations of *A. baylii* from South Australia and Inverloch, Victoria are sexually dimorphic in gonad morphology, whereas *A. thrombolites* lacks sexual dimorphism and

combines features of both sexes of *A. baylii*. Second, the South Australian and Victorian populations are geographically isolated from one another in inland salt lakes approximately 450 km apart, with suitable habitats in between, from which they are apparently absent. While studies of the more common freshwater genus *Craspedacusta* have demonstrated incredible dispersive capability, there are nonetheless several unique forms (see Jankowski 2001), as may be the case for *Australomedusa*.

On a recent field trip (7 Feb 2002) we visited the type locality of *A. baylii* (lake 12 of Bayly 1970) in order to collect fresh material, without success. The small lake known locally as "Lake Wylie" [37°16'48.2"S, 139°49'59.1"E] is located on the Karinya property just east of Lake Eliza, next to the Big Dip Conservation Park, about 17 kms south of Robe. At the time of our study, the temperature was 22.5°C, the salinity 25.5 ppt, and a green algal bloom was apparent. We also sampled two other lakes near the Karinya Homestead, an unnamed lake [37°16'53.9"S, 139°50'E] across the track from Lake Wylie, and one locally known as Lake Pudd [37°17'20.3"S, 139°50'13.5"E], about 1 km south-east of Lake Wylie. No medusae were found in either nearby lake, although both harbored diverse crustacean and molluscan faunas. The water of both lakes was clear, the temperature of both lakes was 22.5°C, and the salinity was 32.0 ppt and 29.5 ppt, respectively.

Thus, in the absence of fresh material, particularly of both sexes from the same locality, we are unable to resolve whether or not the known populations of *A. baylii* represent the same species.

### ACKNOWLEDGEMENTS

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# The aulacid wasp fauna of Western Australia with descriptions of six new species

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**Abstract** – This study describes for the first time the Aulacidae from Western Australia, a fauna that comprises six geographically isolated species. Three new species of *Aulacus*; *A. douglasi*, *A. houstoni*, and *A. mcmillani*, and three new species of *Pristaulacus*; *P. curryi*, *P. davisi*, and *P. mouldsi*, are described. At the same time, a key to genera and species is presented, along with a diagnosis for *Aulacus* and *Pristaulacus*, and notes on their taxonomic history and species diversity.

**Key words:** Evanioidea, Aulacidae, *Aulacus*, *Pristaulacus*, taxonomy, parasitic wasps.

## INTRODUCTION

The Aulacidae is a family of parasitic wasps that are endoparasitoids of wood-boring wasps (Xiphydriidae) and beetles (Cerambycidae and Buprestidae) (Carlson 1979; Gauld and Bolton 1996; Smith 2001; Jennings and Austin in press), although there are no records of aulacids parasitising xiphydriid wasps in Australia. At various times the Aulacidae have been treated as a subfamily or group of the Evaniidae, or as a separate family, but all recent studies accord them family status (e.g. Naumann 1991; Mason 1993; Gauld 1995; Jennings and Austin 2000, in press; Smith 2001). They are included in the superfamily Evanioidea along with the Evaniidae and Gasteruptiidae, and are most closely related to the latter family (Jennings and Austin in press).

Although all Evanioidea are characterised by the high insertion of the metasoma on the propodeum, aulacids are readily distinguished from evaniids and gasteruptiids by the presence of fore wing cross-vein 2m-cu (Gauld and Bolton 1996), and cross-vein 3r-m (Konishi 1990), and the presence of a metapostnotum.

Smith (2001) provided a catalogue of the world aulacid fauna, and included 48 species of *Aulacus* Jurine, 106 species of *Pristaulacus* Kieffer, and two species of *Panaulix* Benoit. Both *Aulacus* and *Pristaulacus* are worldwide in distribution, but *Panaulix* is confined to sub-Saharan Africa.

The Australian fauna comprises some 40 described species (24 for *Aulacus* and 16 for

*Pristaulacus*) (Smith 2001; Jennings 2001; Jennings *et al.* in press), however, most descriptions are inadequate and date from the early part of the 20th Century. Even though modern collecting techniques such as malaise trapping have added significantly to the number of specimens held in museum and other collections, only one taxonomic study, that of Jennings *et al.* (in press), has been undertaken on the Australian fauna in the last 50 years.

This study is part of a project that aims to revise the Aulacidae of Australia, and for the first time treats the fauna of Western Australia which comprises three new *Aulacus* and three new *Pristaulacus* species.

## METHODS, TERMINOLOGY AND ABBREVIATIONS

Specimens were observed under a Zeiss light microscope or using scanning electron microscopy (SEM). Specimens for SEM were first cleaned to remove obvious dirt and other debris and examined uncoated under a Phillips XL30 field emission SEM at 1kV and a spot size of three.

Terms for general morphology follow Jennings and Austin (1994), and that for wing venation follows the modified Comstock-Needham system after Sharkey (1988), but with some modifications, and using the nomenclature of van Achterberg (1979) for cells (Figures 1–2). Terms for surface sculpturing follow Harris (1979), and for male genitalia Crosskey (1951). Where morphometric

measurements are based on more than one specimen, data are presented as the mean followed by the range. The length of the ovipositor is measured from the tip of the metasoma, and the length of the hind femur includes the prefemur (trochantellus).

The abbreviations for the institutions that are the repository of the specimens referred to in this paper are: Western Australian Department of Agriculture (WADA) and Western Australian Museum (WAM).

## SYSTEMATICS

### Key to Western Australian species

Most of the described Australian species of aulacids are from the higher rainfall, forested areas of the east coast. A key to continental fauna is not presented here because there are many undescribed species known in collections. However, because the six species are known only from Western Australia, a key is presented to facilitate their identification.

1. Hind tarsal claw not pectinate ..... *Aulacus*. 2  
Hind tarsal claw pectinate ..... *Pristaulacus*. 4
2. Costal, basal, submarginal, and marginal cells of fore wing dark brown; large species, body length 16.5 mm, excluding ovipositor .....  
..... *A. douglasi*, sp. nov.  
Fore wing cells largely hyaline; smaller species, <12.0 mm in body length, excluding ovipositor ..... 3
3. Brown spot apically on marginal and submarginal cells of fore wing; lateral lobes of mesoscutum strigate; metasomal T1 and T2 broad when viewed dorsally .....  
..... *A. houstoni*, sp. nov.  
Wings entirely hyaline, apical spot on fore wing absent; lateral lobes of mesoscutum rugose; metasomal T1 and T2 narrow when viewed dorsally ..... *A. mcmillani*, sp. nov.
4. Fore wing vein 2-Rs+M long and second discal cell elongate (see Figure 1); small species, 6.0 mm in body length, excluding ovipositor .....  
..... *P. curryi*, sp. nov.  
Fore wing vein 2-Rs+M short and second discal cell more or less quadrate (see Figure 2); larger species, >9.0 mm in body length, excluding ovipositor ..... 5
5. Metasoma clavate; hind wing venation reduced, veins R+Rs, M+Cu and Cu absent, r-m and 2-M largely spectral (Figure 2) .....  
..... *P. davisii*, sp. nov.  
Metasoma ovate; hind wing venation not reduced, R+Rs, M+Cu, Cu, r-2m and 2-M present (see Figure 1) ..... *P. mouldsi*, sp. nov.

### *Aulacus* Jurine, 1807

[For a complete taxonomic history of *Aulacus* see Jennings *et al.* (in press)]

#### Diagnosis based on Australian species

Eyes small, circular or subcircular, remote from the mandibles; antenna 14-segmented in female, 13-segmented in male; antennal insertions low on face, near lower margin of eyes; scape usually deeply convex ventrally in lateral view, much thicker than pedicel and flagellomeres; sub-antennal groove or depression to accommodate scape (e.g. Figure 8); metapostnotum between propodeum and metanotum as a distinct sclerotisation (Figures 18–19); propodeum pyramidal, metasoma inserted high on the apex; metasomal T1 and T2 fused dorsally; hind coxa usually with groove or notch on inner lateral surface, the apposed grooves or notches forming an ovipositor guide; hind trochanter with a transverse trochanteral groove (Figure 16), prefemur (trochantellus) present (Figure 16); each tarsal claw with one basal tooth (sometimes difficult to see); fore wings not plicate at rest; fore wing vein 2m-cu present (Figure 1), vein 2r-m usually present, largely spectral, vein 3r-m present, often largely spectral (Figure 1); ovipositor exerted, protruding well beyond apex of metasoma.

#### Comments

*Aulacus* currently includes all aulacids with non-pectinate hind tarsal claws and includes 51 species worldwide, 21 of which are endemic to Australia (Smith 2001; Jennings 2001; Jennings *et al.* in press).

### *Aulacus douglasi* sp. nov.

Figures 11, 16, 18, 29

#### Material Examined

##### Holotype

♀. "38-407, Wubin" "A. Douglas". (WAM). Right antennal flagellomeres 2–12, left antennal flagellomere 12, right fore tarsi, mid legs, right hind tibia and tarsi, and left ovipositor sheath missing.

##### Female

*Length.* 16.5 mm, excluding ovipositor.

*Colour.* Body orange-red, with variable amounts of dark brown on mandibles, malar space, lateral mesoscutum, mesepisternum, mesepimeron, and metasomal T3 and T4; ovipositor brown; wings generally pale brown, costal, basal, submarginal and marginal cells darker brown.

*Head.* 1.24 x wider than long when viewed dorsally; face rugose, pubescence short; distinct sub-antennal groove; frons with weak lateral medial carina above toruli, rugose, with short

pubescence; vertex imbricate, with scattered short setae; gena imbricate, slightly rugulose ventrally near eye margin, with scattered short setae; posterior margin of head not concave in dorsal view; occipital carina absent; malar space  $0.2 \times$  height eye; clypeus  $4.0 \times$  as wide as high, margin sinuate, medial process present; distance from lateral ocellus to eye margin  $0.86 \times$  distance between lateral ocelli; scape  $2.1 \times$  length pedicel; first flagellomere  $0.8 \times$  as long as scape,  $1.0 \times$  as long as second flagellomere.

*Mesosoma.* Propleuron rugulose, pubescence short, ventro-lateral carina weak; pronotum without angular process, rugulose-imbricate; mesoscutum in lateral view rounded antero-dorsally, medial and lateral lobes rugose (Figure 11), with scattered short setae, admedial lines present, weak; scutellum and axillae rugulose (Figure 18); metapostnotum rugose, posterior margin scrobiculate (Figure 18); mesepisternum rugose, with short pubescence; mesepimeron broad, carinate; metapleuron coarsely rugose, with short pubescence; propodeum coarsely rugose, posterior margin scrobiculate; hind coxa rugose dorsally, smooth laterally, pubescence short laterally, ovipositor guide on inner surface, medial; hind trochanter weakly imbricate, with scattered short setae (Figure 16); hind prefemur on hind leg present; hind femur imbricate, with scattered short setae; hind tibia imbricate, pubescence short, with scattered stout emergent setae; hind femur  $0.75 \times$  length hind tibia; hind tibia with ventro-apical pecten of short robust spines; hind tarsal segments 1–4 with ventro-apical pecten of short robust spines, segment 1,  $2.6 \times$  length segment 2; segment 2,  $1.6 \times$  length segment 3; segment 3,  $1.5 \times$  length segment 4; segment 4,  $0.7 \times$  length segment 5; hind tarsal claw  $0.45 \times$  length segment 5; fore wing vein 2-Rs+M long, second discal cell elongate, veins 2r-m and 3r-m largely spectral; hind wing venation complete, R+Rs, M+Cu, Cu, r-m and 2-M present, with 2 hamuli.

*Metasoma.* Clavate,  $1.75 \times$  length of mesosoma; T1 and T2 narrow, smooth; ovipositor 18.8 mm.

#### Male

Unknown.

#### Remarks

*Aulacus douglasi* has a distinctive fore wing colouration in that the costal, basal, submarginal and marginal cells are dark brown, and this distinguishes it from the other Western Australian species. Although *A. douglasi* is similar to the fore wing colouration of *A. festivus* (Kieffer) from Queensland, the latter species differs in many ways including having more extensive black colouration on the head, body, and metasoma, and a smooth vertex. *Aulacus douglasi* is known only from the holotype locality, Wubin, Western Australia (Figure

29), and is named after the collector, Athol Douglas. Nothing is known of its biology.

#### *Aulacus houstoni* sp. nov.

Figures 1, 3, 9, 12, 19, 29

#### Material Examined

##### Holotype

♀. "Fitzgerald River Nat. Pk. (NW Sector), Western Australia, 9–11 April 1982, T.F. Houston 444". (WAM).

##### Female

*Length.* 11.0 mm, excluding ovipositor.

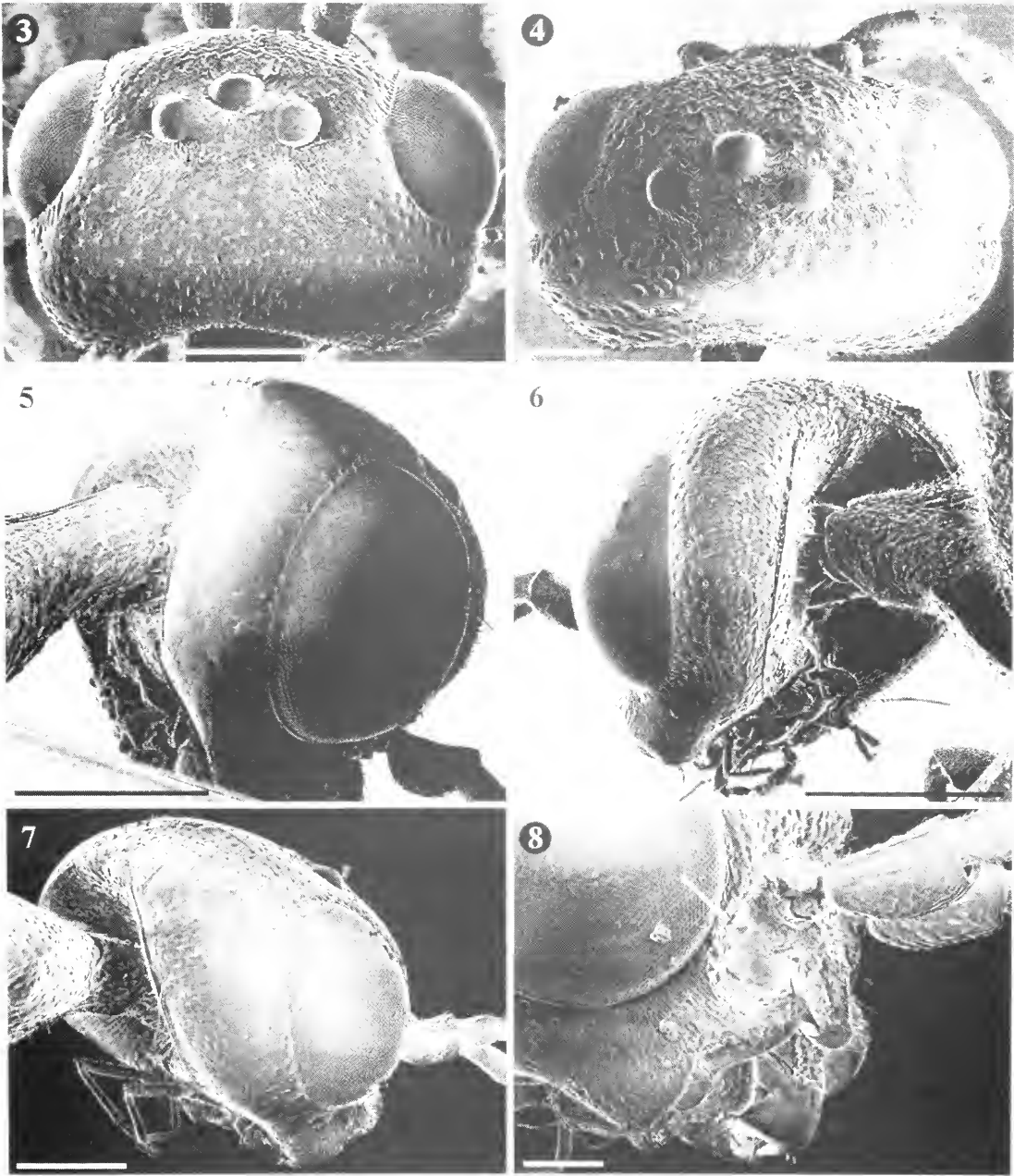
*Colour.* Body orange-brown except flagellomeres and ovipositor sheaths dark brown; mesoscutum, scutellum, axillae, metanotum, mesepisternum, metapleuron, propodeum, and metasomal T1 with variable amounts of dark brown; wings pale brown, fore wing with darker spot apically on the marginal and submarginal cells.

*Head.*  $1.5 \times$  wider than long when viewed dorsally (Figure 3); face, frons, vertex and gena punctate-imbricate, with scattered short setae; shallow sub-antennal groove; frons with slight lateral protrusion above toruli; posterior margin of head slightly concave in dorsal view; occipital carina absent; malar space  $0.33 \times$  height eye; clypeus  $4.6 \times$  as wide as high, margin sinuate, distinct medial process (Figure 9); distance from lateral ocellus to eye margin  $0.9 \times$  distance between lateral ocelli; scape  $1.3 \times$  length pedicel; first flagellomere  $1.06 \times$  as long as scape,  $0.65 \times$  as long as second flagellomere.

*Mesosoma.* Propleuron rugulose medially, imbricate and with scattered short setae laterally, ventro-lateral carina weak; pronotum without angular process, rugulose and with scattered punctures; mesoscutum in lateral view rounded antero-dorsally, medial and lateral lobes strigate, with underlying punctate-imbricate sculpturing, with scattered short setae, admedial lines present (Figure 12); scutellum and axillae weakly strigate (Figure 19), with underlying punctate-imbricate sculpturing; metapostnotum scrobiculate, posterior margin distinctly convex (Figure 19); mesepisternum rugulose dorsally, smooth medially, rugose-punctate ventrally, with short setae, denser ventrally; mesepimeron broad, carinate; metapleuron rugulose dorsally, smooth medially, rugose-punctate ventrally with short setae; propodeum coarsely rugose, smooth medially and with a median dorso-ventral carina, posterior margin scrobiculate; hind coxa rugose dorsally, imbricate laterally, pubescence short, ovipositor guide on inner side, somewhat distal, pronounced ventral lobe on outer side; hind trochanter imbricate, pubescence short; prefemur on hind leg







**Figures 3–8** 3–4. Dorsal view of head of (3) *A. houstoni* sp. nov., holotype female; (4) *A. mcmillani* sp. nov., holotype male. 5–7. Postero-lateral view of head of (5) *P. curryi* sp. nov., holotype female; (6) *P. mouldsi* sp. nov., holotype female; (7) *P. davisi* sp. nov., holotype female. 8. Lateral view of lower head showing sub-antennal groove of *P. davisi* sp. nov., holotype female. Scale bars = 3, 5, 7, 500  $\mu$ m; 4, 8, 200  $\mu$ m; 6, 1 mm

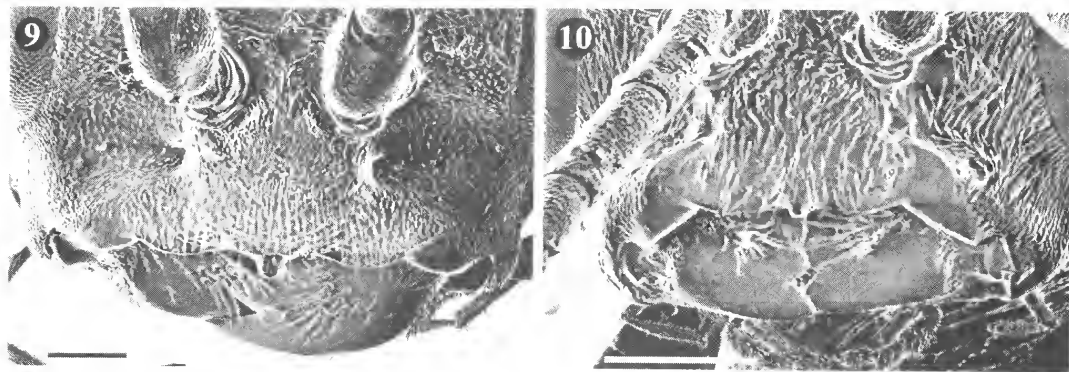
*Aulacus mcmillani* sp. nov.  
 Figures 4, 27, 29

**Material Examined**

*Holotype*  
 ♂. "Kings Park. Emerged 4.i.1958 from larva coll.

2.xi.1957. R.P. McMillan." (WAM). Left antenna and right hind tarsi missing.

*Paratype*  
 Western Australia: 1 ♂, same data as holotype (WAM).



Figures 9–10 Clypeal region and mandibles of (9) *A. houstoni* sp. nov., holotype female; (10) *P. mouldsi* sp. nov., holotype female. Scale bars = 9, 200 µm; 10, 500 µm.

#### Other specimens examined

**Western Australia:** 1 ♀, same data as holotype (WAM); 2 pupae, Kings Park, 17.xi.1957, R.P. McMillan (WAM).

#### Male

*Length.* 7.1 mm.

*Colour.* Body and head dark brown, legs and metasoma yellow brown. Wings hyaline.

*Head.* Width:length 1.5 when viewed dorsally (Figure 4); distinct sub-antennal groove; face rugose, with scattered long setae; frons without lateral carina above toruli, punctate-imbricate, with scattered short setae; vertex punctate-imbricate, with scattered short setae; gena weakly rugulose, with scattered short setae; posterior margin of head not concave in dorsal view; occipital carina absent; malar space 0.3 x height eye; clypeus 3.3 x as wide as high, margin sinuate with small medial process; distance from lateral ocellus to eye margin 0.8 x distance between lateral ocelli; scape 1.7 x length pedicel; first flagellomere 0.7 x as long as scape, 0.9 x as long as second flagellomere.

*Mesosoma.* Propleuron punctulate-imbricate, pubescence long, ventro-lateral carina present; pronotum without angular process, rugulose, with a few scattered punctures; mesoscutum in lateral view rounded antero-dorsally, medial and lateral lobes rugose, with a few scattered short setae, admedial lines present; scutellum and axillae rugose; metapostnotum rugose, posterior margin scrobiculate; mesepisternum rugose, with short pubescence; mesepimeron broad, scrobiculate; metapleuron rugose, with short pubescence; propodeum rugose dorsally, areolate laterally and medially, posterior margin weakly scrobiculate laterally; hind coxa strigate dorsally, rugose laterally, pubescence long laterally; hind trochanter imbricate, with scattered long setae; hind prefemur present; hind femur imbricate, with short pubescence; hind tibia imbricate, pubescence short,

with scattered emergent stout setae; hind femur 0.67 x length hind tibia; hind tibia with ventro-apical pecten of short robust spines; hind tarsal segments 1–4 with ventro-apical pecten of short robust spines, segment 1, 2.8 x length segment 2; segment 2, 1.5 x length segment 3; segment 3, 1.3 x length segment 4; segment 4, 0.75 x length segment 5; hind tarsal claw 0.6 x length segment 5; fore wing vein 2-Rs+M long, second discal cell elongate, 2r-m absent, 3r-m spectral medially; hind wing venation reduced, M+Cu and Cu absent, with 3 hamuli.

*Metasoma.* Clavate, 1.65 x length of mesosoma; T1 and T2, narrow, smooth dorsally; basiparameres broad, imbricate (Figure 27); digitus broad, slightly longer than basiparameres (Figure 27).

#### Female

*Note:* The specimen has not fully emerged from the cocoon. Similar to male except: length 8.0 mm; ovipositor at least 10.0 mm long; ovipositor guide on hind coxae present.

#### Pupa

5.3 mm in length, exarate, covered with a pale brown testaceous cocoon.

#### Remarks

This species is the smallest of the Western Australian *Aulacus* species, and can be readily separated from the other species by its size and the characters in the key.

All known specimens were bred from cerambycid larvae (unknown species) collected in Kings Park, Perth, Western Australia (Figure 29). The species is named after the collector, R.P. McMillan.

#### *Pristaulacus* Kieffer, 1900

*Aulacostethus* Philippi 1873: 302. Type species:

*Aulacostethus rubiventer* Philippi, by monotypy

- (preoccupied by Waterhouse 1869 (Coleoptera), Uhler 1871 (Hemiptera—see Smith 2001). – Townes 1950: 88; Townes 1951: 657; Crosskey 1953: 759.
- Aulacostethus* Schletterer 1889: 523. Misspelling of *Aulacostethus*.
- Pristaulacus* Kieffer 1900: 813. Type species: *Pristaulacus chlapowskii* Kieffer, designated by Kieffer 1903: 455. Kieffer 1903: 378, 382, 455; Kieffer 1904: 7; Schmiedeknecht 1907: 493, 501; Bradley 1908: 121, 126; Kieffer 1911: 215, 227; Kieffer 1912: 376; Schmiedeknecht 1914: 194; Hedicke 1930: 76; Schmiedeknecht 1930: 81; Hedicke 1939: 4; Oehlke 1983: 441; Koslov 1988: 243; Konishi 1990: 641; Aleeksev 1995: 39; Smith 2001: 277.
- Deraidontus* Bradley 1901a: 29. No species included. Type species: *Aulacus montanus* Cresson, by subsequent designation, first included species by Bradley 1901b: 321. – (syn. Kieffer 1903: 382).
- Oleisoprister* Bradley 1901b: 324. Type species: *Aulacus firmus* Cresson, by original designation. – Kieffer 1903: 382; Bradley 1908: 121. (syn. Kieffer 1911: 227).
- Aulacostathus* Dalla Torre 1902: 1062. Misspelling of *Aulacostethus*.
- Anaulacus* Semenow 1903: 173. Type species: *Aulacus sibiricola* Semenow, by subsequent designation of Bradley 1908: 120. Preoccupied by MacLeay 1825 (Coleoptera) (see Smith 2001).
- Semenowia* Kieffer 1903: 382. New name for *Anaulacus* Semenow. Preoccupied by Weise 1889 (Coleoptera) (see Smith 2001). – Kieffer 1904: 720. (syn. of *Odontaulacus* Kieffer 1912: 365).
- Odontaulacus* Kieffer 1903: 382. Type species: *Aulacus rufitarsis* Cresson, designated by Bradley 1908: 120. – Bradley 1908: 120; Kieffer 1911: 215; Kieffer 1912: 365; Hedicke 1939: 20; Aleeksev 1995: 39. (syn. of *Aulacostethus* Townes 1950: 88).
- Semenovius* Bradley 1908: 120. New name for *Semenowia* Kieffer. – Townes 1950: 88.
- Tropaulacus* Bradley 1908: 120. Type species: *Tropaulacus torridus* Bradley, by original designation. – Kieffer 1911: 215; Kieffer 1912: 362; Hedicke 1939: 17. (syn. of *Aulacostethus* Townes 1950: 88).
- Pristaulacus* (*Neaulacus*) Bradley 1908: 121. Type species: *Aulacus occidentalis* Cresson, by original designation. – (syn. Kieffer 1911: 227).
- Interaulacus* Bradley 1908: 120. Type species: *Interaulacus kiefferi* Bradley, by original designation. – Kieffer 1911: 215; Kieffer 1912: 376; Hedicke 1939: 20. (syn. Smith 2001: 280).
- Tetraulacinus* Kieffer 1910: 350. No species included. Type species: *Pristaulacus rufobalteatus* Cameron, by subsequent monotypy, first species included by Kieffer 1911: 214. – Kieffer 1912: 363; Hedicke 1939: 17. (syn. of *Aulacostethus* Townes 1950: 88).
- Psilaulacus* Kieffer 1910: 350. No species included. Type species: *Psilaulacus annulatus* Kieffer, by subsequent monotypy, first species included by Kieffer 1911: 215. – (syn. Kieffer 1912: 376).
- Aulacosthetus* Kieffer 1912: 370. Misspelling of *Aulacostethus*.
- Aulacomastus* Muesebeck and Walkley 1956: 333. Unnecessary new name for *Aulacostethus* Philippi.
- Odontaculus*: Koslov 1988: 242. Misspelling of *Odontaulacus*.

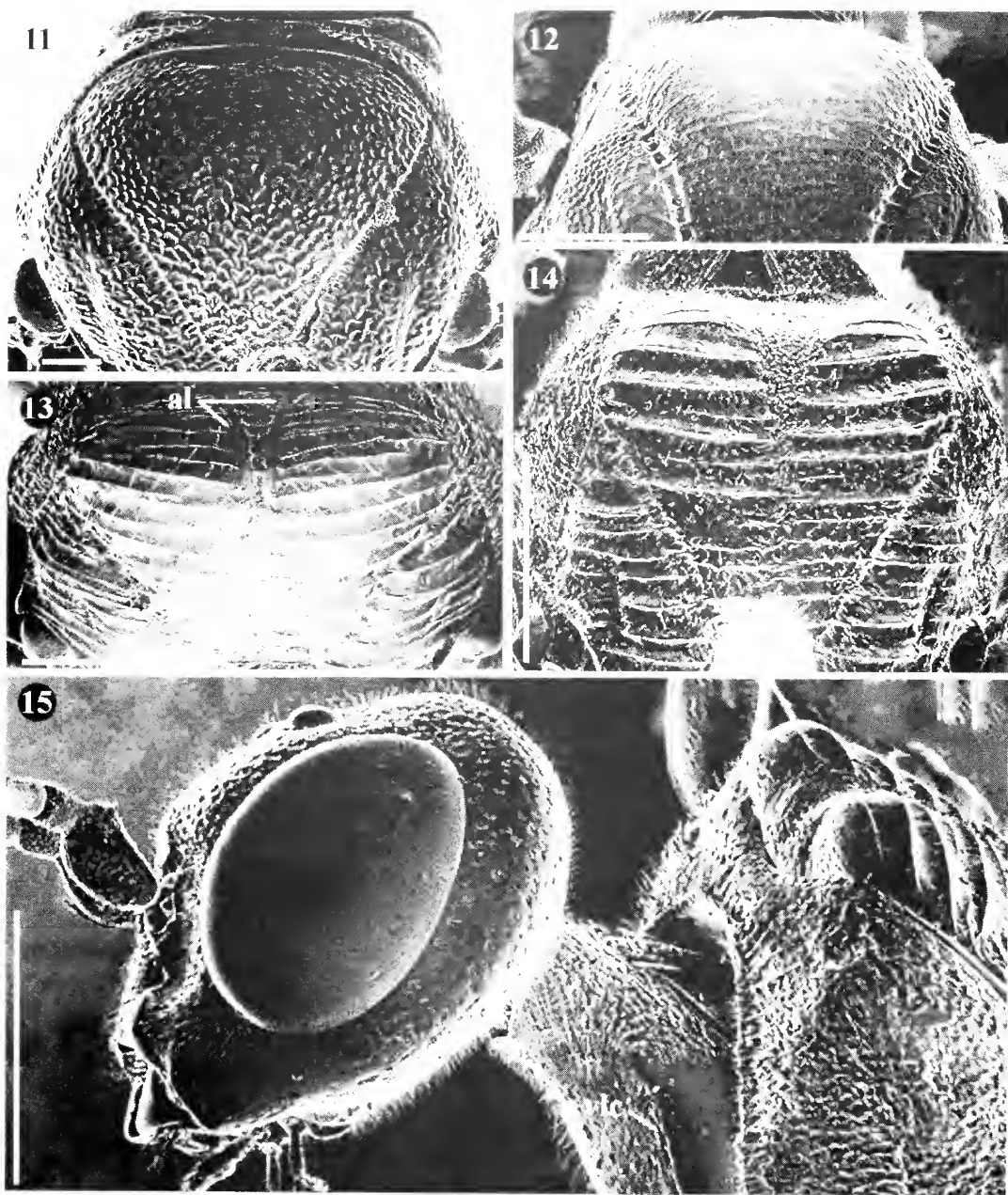
### Diagnosis based on Australian species

As for *Aulacus* except: each tarsal claw pectinate, with one basal tooth (sometimes difficult to see) and one or more medial teeth.

### Comments

The genus *Aulacostethus* was erected by Philippi (1873), but *Aulacostethus* was preoccupied by a beetle and a hemipteran. In 1900, Kieffer erected *Pristaulacus* to include all taxa previously included in *Aulacostethus*. However, a degree of confusion continued for many years as a number of authors, notably Townes (1950) and Crosskey (1953), continued to use *Aulacostethus*.

As with *Aulacus*, early authors had not established the generic limits of *Pristaulacus*, so that a number of genera were erected to include specific variation. These included *Anaulacus* Semenow from Siberia, *Deraidontus* Bradley, *Oleisoprister* Bradley, and *Tropaulacus* Bradley from North America, *Odontaulacus* Kieffer from South and North America, and Australia, *Interaulacus* Bradley from South America, *Psilaulacus* Kieffer from Mexico, and *Tetraulacinus* Kieffer from India. By 1912, Kieffer had included some 84 species in his world catalogue and synonymised *Semenovius* with *Odontaulacus* and *Psilaulacus* with *Pristaulacus*. Townes (1950) provided a degree of generic stability by placing *Odontaulacus*, *Tropaulacus*, and *Tetraulacinus* into synonymy with *Aulacostethus*, although he failed to recognise that *Aulacostethus* had been synonymised with *Pristaulacus*. Townes also erroneously synonymised *Disaulacinus* with *Aulacostethus*; *Disaulacinus* is now considered a synonym of *Aulacus*. Oehlke (1983) and others recognised only the genus *Pristaulacus* to define those aulacids with pectinate hind tarsal claws. In his recent catalogue, Smith (2001) included 106 species in *Pristaulacus*, including 16 from Australia.



**Figures 11–15** 11–14. Dorsal view of mesoscutum of (11) *A. douglasi* sp. nov., holotype female; (12) *A. houstoni* sp. nov., holotype female; (13) *P. curryi* sp. nov., holotype female; al = admedial line; (14) *P. mouldsi* sp. nov., holotype female. 15. Lateral view of head and mesoscutum of *P. mouldsi* sp. nov., holotype female; vlc = ventro lateral carina. Scale bars = 11–13, 500  $\mu$ m; 14–15, 1 mm.

*Pristaulacus curryi* sp. nov.

Figures 13, 20, 23, 26, 28–29

**Material Examined**

*Holotype*

♀. "Jarrahdale W. Aust., Ex *E. microcorys*, Feb

1974, S.J. Curry" (WADA). Right antenna missing.

*Paratypes*

**Western Australia:** 1 ♂, N Yanchep, 6.ii.1968, S.J. Curry (WADA); 1 ♂, Ludlow, 20.iii.1968, S.J. Curry (WADA); 2 ♀♀, Dwellingup, 24.ii.1970, S.J. Curry

(WADA); 4 ♀♀, Jarrahdale, 21.i.1974, S.J. Curry (WADA).

#### Female

*Length.* 6.0 (5.7–6.5) mm, excluding ovipositor.

*Colour.* Body black. Scape, clypeus, legs and metasomal T1 and T2 light brown; wings hyaline except for a small fuscous spot at tip of fore wing.

*Head.* Width:length 1.2 when viewed dorsally; face rugose, pubescence short; sub-antennal groove smooth; frons rugose-punctate near toruli to punctate near ocelli, lateral carina above toruli, absent, with scattered short setae, denser near toruli; vertex and gena smooth, shiny except for a few scattered shallow punctures, each associated with a short seta; posterior margin of head slightly concave in dorsal view; occipital carina complete (Figure 5); malar space 0.3 (0.26–0.33) × height eye; clypeus 4.4 (4.2–4.8) × as wide as high, margin sinuate, with small medial process; distance from lateral ocellus to eye margin 0.46 (0.4–0.5) × distance between lateral ocelli; scape 1.7 (1.6–1.75) × length pedicel; first flagellomere 1.3 (0.9–1.4) × as long as scape, 1.24 (1.09–1.36) × as long as second flagellomere.

*Mesosoma.* Propleuron rugose, pubescence short, ventro-lateral carina present; pronotum without angular process, rugose; mesoscutum in lateral view angular antero-dorsally, medial and lateral lobes carinate with scattered short setae, admedial lines slightly curved (Figure 13); scutellum and axillae carinate (Figure 20); metapostnotum broad, depressed, rugose, scrobiculate posterior margin (Figure 20); mesepisternum rugose, with long pubescence; mesepimeron broad, scrobiculate; metapleuron rugose, with long pubescence; propodeum coarsely rugose, posterior margin coarsely scrobiculate; hind coxa rugulose, distinct flange-like ovipositor guide on inner side, distal (Figure 26); hind trochanter imbricate, with distinct groove, with scattered long setae; prefemur on hind leg present; hind femur imbricate, pubescence short; hind tibia imbricate, pubescence short, with scattered emergent stout brown setae; hind femur 0.82 (0.79–0.86) × length hind tibia; hind tibia with ventro-apical pecten of short robust spines; hind tarsal segments 1–4 with ventro-apical pecten of short robust spines, segment 1, 2.8 (2.2–3.2) × length segment 2; segment 2, 1.4 (1.35–1.60) × length segment 3; segment 3, 1.4 (1.3–1.6) × length segment 4; segment 4, 0.7 (0.6–0.8) × length segment 5; hind tarsal claw pectinate, with one large medial and one small basal tooth (difficult to see), 0.5 × length segment 5; fore wing vein 2-Rs+M long, second discal cell elongate, vein 2r-m largely spectral; 3r-m tubular in anterior third and posterior tenth, remainder spectral; hind wing venation complete, R+Rs, M+Cu, Cu, r-m and 2-M present, with 2 hamuli.

*Metasoma.* Clavate, 1.07 (1.05–1.10) × length of mesosoma; T1 and T2, narrow, smooth (Figure 25); ovipositor 4.7 (3.4–5.2) mm.

#### Male

Similar to female except: length 6.7 (6.5–6.8) mm; wings entirely hyaline; metasoma narrower; digitus about same length as basiparameres (Figure 28); basiparameres narrow and smooth, except shallow punctures, each associated with a somewhat stout seta (Figure 28).

#### Remarks

The male of this species is slightly larger than the female and can be distinguished from the female by the absence of the fuscous tip on the fore wings, as well as by having 13 antennal segments, typical of male aulacids.

*Pristaulacus curryi* can be readily distinguished from the other two Western Australian species by its small size. Both *P. davisi* and *P. mouldsi* have a body length of more than 10.0 mm compared with 6.0 (5.7–6.5) mm for *P. curryi*. Also, the fore wing vein 2-Rs+M is short and the second discal cell is more or less quadrate in *P. davisi* (Figure 2) and *P. mouldsi*, whereas in *P. curryi*, vein 2-Rs+M is long and the second discal cell is elongate (see Figure 1).

All specimens of *P. curryi* emerged from timber of various *Eucalyptus* species, jarrah (*E. marginata*), tallowwood (*E. microcorys*) and tuart (*E. gomphocephala*), although the beetle host is unknown. This species has been collected from a number of localities in south-western Western Australia (Figure 29), and has been named after the collector, Stephen Curry.

#### *Pristaulacus davisi* sp. nov.

Figures 2, 7–8, 17, 21, 25, 29

#### Material Examined

##### Holotype

♀. "Sawyer[s] Valley, W.A., Dec." (WADA). Left flagellomeres 7 to tip and right 8 to tip, front right femur and tarsi, mid tarsi, and hind tibiae and tarsi missing.

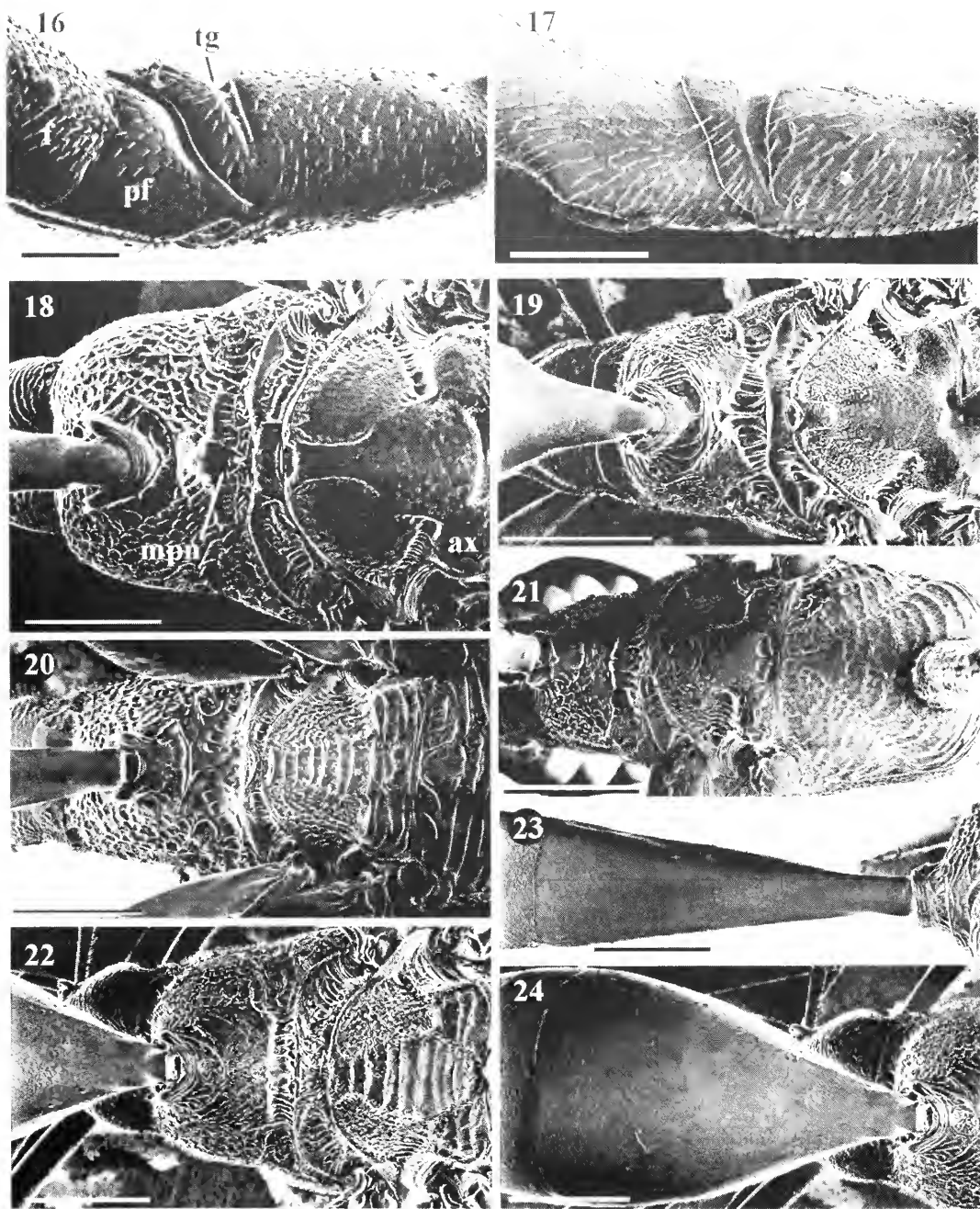
##### Female

*Length.* 10.0 mm, excluding ovipositor.

*Colour.* Body brown, head, antennae, pronotum, and hind trochanters and femorae black, last few metasomal segments darker brown, wings hyaline, pale brown, fore wing costal cell darker.

*Head.* Width:length 1.25 when viewed dorsally; face rugulose, pubescence long; sub-antennal groove smooth, shiny (Figure 8); frons without lateral carina above toruli, shiny, punctate, with scattered short setae, denser and longer near toruli;





**Figures 16–24** (16) Lateral view of hind trochanter, prefemur, and femur of *A. douglasi* sp. nov., holotype female; tg = trochanteral groove, pf = prefemur (trochantellus), f = femur. (17) Lateral view of hind trochanter and prefemur of *P. davisi* sp. nov., holotype female. Scale bars = 200 µm. Dorsal view of scutellum of (18) *A. douglasi* sp. nov., holotype female; sc = scutellum, ax = axilla, mpn = metapostnotum; (19) *A. houstoni* sp. nov., holotype female; (20) *P. curryi* sp. nov., holotype female; (21) *A. davisi* sp. nov., holotype female; (22) *P. mouldsi* sp. nov., holotype female. Dorsal view of T1 and T2 of (23) *P. curryi* sp. nov., holotype female; (24) *P. mouldsi* sp. nov., holotype female. Scale bars = 16–17, 200 µm. 18–19, 21–22, 24, 1 mm; 20, 23, 500 µm.

vertex and gena shiny, punctate, with scattered short setae; posterior margin of head not concave in dorsal view; occipital carina present laterally, absent medially (Figure 7); malar space  $0.25 \times$  height eye; clypeus  $5.0 \times$  as wide as high, with sinuate margin, small medial process present; distance from lateral ocellus to eye margin  $0.65 \times$  distance between lateral ocelli; scape  $1.6 \times$  length pedicel; first flagellomere  $2.0 \times$  as long as scape,  $0.75 \times$  as long as second flagellomere.

**Mesosoma.** Propleuron smooth, shiny, with scattered shallow punctures, each associated with a long seta, ventro-lateral carina present; pronotum without angular process, rugose-punctate in dorsal part to punctate in ventral part; mesoscutum in lateral view rounded antero-dorsally, medial and lateral lobes coarsely strigate, with scattered short setae, admedial lines not visible; scutellum and axillae strigate (Figure 21); posterior margin of metapostnotum scrobiculate, weakly convex (Figure 21); mesepisternum and metapleuron rugose, with long pubescence; mesepimeron broad, scrobiculate; propodeum rugose, almost areolate medially, posterior margin scrobiculate; hind coxa rugose with lateral striations dorsally, pubescence long laterally, ovipositor guide on inner side, distal, indicated by bulge on ventral surface (Figure 25); hind trochanter with broad groove (Figure 17), imbricate, pubescence long; prefemur indistinct

(Figure 17); hind femur imbricate, with short pubescence; hind tibiae and tarsi missing; fore wing vein 2-Rs+M short, second discal cell more or less quadrate, vein 2r-m almost absent except for slight node on medial vein (Figure 2); 3r-m tubular in anterior quarter, remainder spectral (Figure 2); hind wing venation reduced, veins r-m and 2-M spectral except for distal 2-M (Figure 2), with 3 hamuli.

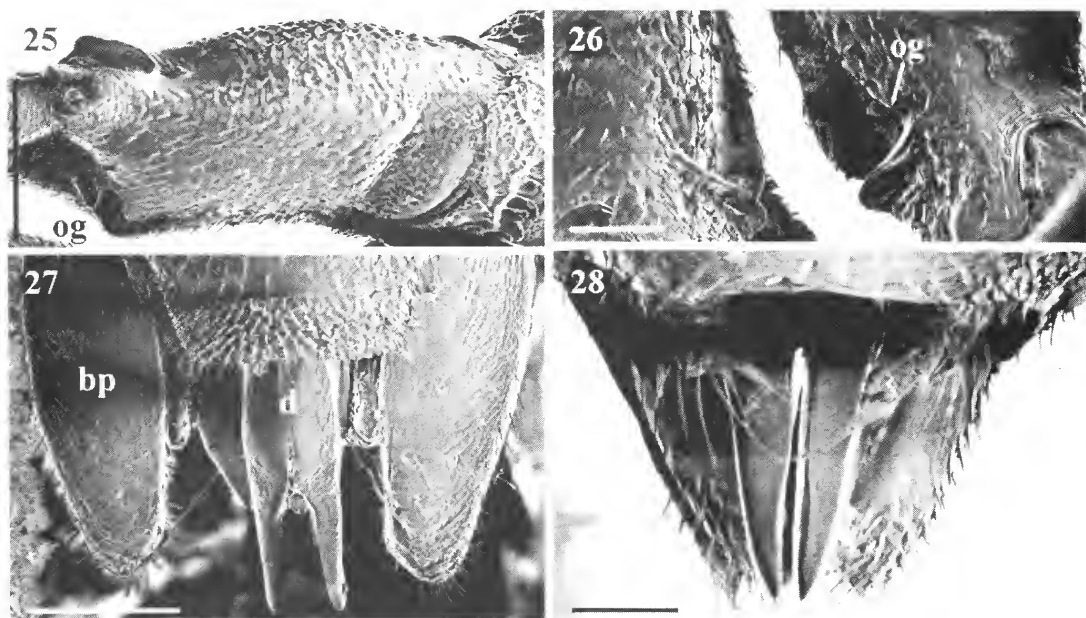
**Metasoma.** Clavate,  $1.5 \times$  length of mesosoma; T1 and T2, narrow, smooth dorsally; ovipositor 8.0 mm.

#### Male

Unknown.

#### Remarks

*Pristaulacus davisi* can be separated from *P. curryi* by its larger size, and from *P. mouldsi* by the hind wing venation, which is reduced (Figure 2). This species also has the metasomal T1 and T2 narrow whereas these are broad in *P. mouldsi*. Several eastern Australian species have a similar dark costal cell on the fore wing to that of *P. davisi*, but these species are quite different, particularly in size and colouration. They include *P. cingulatus* (Westwood) that is 9–12 mm in length and largely red-brown, *P. lateritius* (Shuckard) that is 12–20 mm in length and red-brown and black, and a number of undescribed taxa.



**Figures 25–28** 25. Lateral view of hind coxa showing position of ovipositor guide of *P. davisi* sp. nov., holotype female; og = ovipositor guide. 26. Dorsal view of ovipositor guide on inner hind coxal surface of *P. curryi* sp. nov., holotype female; og = ovipositor guide. 27–28. Adeagus of (27) *A. mcmillani* sp. nov., holotype male; bp = basiparamere, d = digitus; (28) *P. curryi* sp. nov., paratype male. Scale bars = 25, 500  $\mu$ m; 26, 100  $\mu$ m; 27, 200  $\mu$ m; 28, 50  $\mu$ m.

This species is named after Peter Davis, entomologist, Department of Agriculture, Western Australia. It is known only from the holotype locality, Sawyers Valley, Western Australia (Figure 29), and nothing is known of its biology.

*Pristaulacus mouldsi* sp. nov.

Figures 6, 10, 14–15, 22, 24, 29

**Material Examined**

*Holotype*

♀. "Lake Cronin, W. Aust., 16.ii.1974, K.T. Richards" (WADA).

*Paratype*

**Western Australia:** 1 female, Norseman, [19]37. No other data. (WAM). Left hind leg missing except for coxa, right hind leg missing except for coxa and trochanter.

*Female*

*Length.* 10.8 (10.3–11.4) mm, excluding ovipositor.

*Colour.* Body dark brown to black, clypeus, legs, metasoma and ovipositor brown. Wings hyaline, pale brown.

*Head.* Width:length 1.75 when viewed dorsally; face rugose, pubescence long; sub-antennal groove present; frons without lateral carina above toruli, punctate-rugose, with short pubescence; vertex and gena punctate-imbricate with scattered short setae; posterior margin of head concave in dorsal view; occipital carina absent medially, weak laterally (Figure 6); malar space 0.3 x height eye; clypeus 6.75 x as wide as high, margin sinuate, with small medial process (Figure 10); distance from lateral ocellus to eye margin 0.7 x distance between lateral ocelli; scape 1.05 (1.0–1.1) x length pedicel; first flagellomere 1.1 (1.0–1.2) x as long as scape, 0.65 (0.6–0.7) x as long as second flagellomere.

*Mesosoma.* Propleuron punctate, pubescence long laterally, ventro-lateral carina flange-like (Figure 15); pronotum without angular process, rugose; mesoscutum in lateral view angular antero-dorsally (Figure 15), medial and lateral lobes carinate with scattered short setae, admedial area depressed (Figures 14–15); scutellum and axillae carinate (Figure 22); metapostnotum narrow, scrobiculate, posterior margin straight (Figure 22); mesepisternum rugose with long pubescence; mesepimeron broad, scrobiculate; metapleuron rugose, with long pubescence; propodeum rugose, a few striations dorsally, posterior margin scrobiculate, hind coxa punctate with a few lateral striations dorsally, rugose laterally, pubescence long laterally, ovipositor guide on inner side, distal, almost at apex; hind trochanter imbricate, with distinct groove, with scattered short setae; hind femur imbricate, pubescence short; hind tibia

imbricate, pubescence short, with scattered emergent stout setae; prefemur on hind leg present; hind femur 0.8 x length hind tibia; hind tibia with ventro-apical pecten of very short robust spines; hind tarsal segments 1–4 with ventro-apical pecten of short robust spines, segment 1, 3.2x length segment 2; segment 2, 1.3 x length segment 3; segment 3, 1.8 x length segment 4; segment 4, 0.6 x length segment 5; hind tarsal claw with two medial and one basal teeth (this difficult to see), 0.6 x length segment 5; fore wing vein 2-Rs+M short, second discal cell more or less quadrate, vein 2r-m absent, 3r-m tubular in anterior third, remainder spectral; hind wing venation reduced, veins r-m and 2-M spectral, with 2 hamuli.

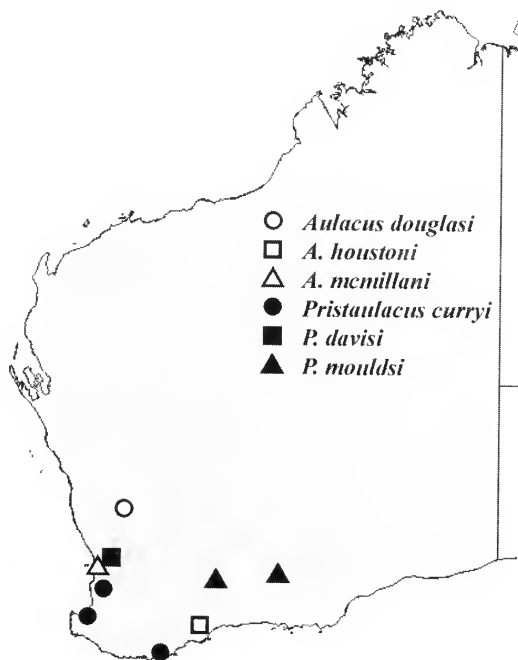
*Metasoma.* Clavate, 1.0 (0.9–1.1) x length of mesosoma; T1 and T2, broad, smooth except for a few shallow punctures laterally (Figure 24); ovipositor 8.0 (7.5–8.5) mm.

*Male*

Unknown.

**Remarks**

*Pristaulacus mouldsi* is the only Western Australian species with the metasomal T1 and T2 broad. It has been collected from two localities in the central, south-west of Western Australia (Figure 29), and is named after Max Moulds, formerly Collection Manager, Entomology at the Australian Museum. Nothing is known of the biology of this species.



**Figure 29** Distribution map of Western Australian Aulacidae.



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## Revision of the genus *Dasyhesma* Michener (Apoidea: Colletidae: Euryglossinae)

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**Abstract** – The endemic Australian bee genus *Dasyhesma* known from two species is revised with the following nineteen (19) species described as new: *D. albula*, *D. argentea*, *D. areola*, *D. aurea*, *D. baeckea*, *D. bolarti*, *D. brevipalpa*, *D. clypeata*, *D. coolgardensis*, *D. depressa*, *D. dilata*, *D. forrestii*, *D. galbina*, *D. lepidophyllae*, *D. muelleriana*, *D. scholtziae*, *D. simulata*, *D. spicata*, *D. syntoma*. All 21 species are known only from Western Australia.

A key enables separation of species. Known distributions are mapped.

### INTRODUCTION

Large numbers of new bee species are constantly being discovered in the Australian endemic subfamily Euryglossinae of the primitive family Colletidae. This is particularly true of larger species (> 6mm) from Western Australia where Dr Terry Houston of the Western Australian Museum has collected from the often endemic wild flowers characteristic of the south-western area of that state. Among the collections are two groups of robust bees in which the head and mesosoma are coarsely and strongly punctate and the propodeum in profile is almost completely vertical. One of these groups in which females are about 10mm long is currently considered the *crabronica* species-group of the genus *Euhesma* (Exley 2002). The second group in which females are 6–9mm long is here considered to be in the genus *Dasyhesma* Michener.

### Relationships

Female *Dasyhesma* species are readily distinguished from the *Euhesma crabronica* species-group by size, wing venation –junction of 2<sup>nd</sup> recurrent vein and 2<sup>nd</sup> submarginal cell cf. Figure 2 with Figure 1 in Exley (2002), metasomal colour markings and basitibial plate (closed in *crabronica* group) open i.e. not completely bounded by carinae in *Dasyhesma*. Although few males were recognised in the *crabronica* group, the genitalia, seventh and eighth metasomal sterna (Exley, 2002 Figures 5–10) are quite different from those of *Dasyhesma* (Figures 16–34).

It is possible the *E. crabronica* group will be removed from the genus *Euhesma* eventually. There are still too many undescribed species and groups of species placed in the genus to make final decisions about its boundaries.

Dissection of *Dasyhesma* males has revealed

similarities with the genus *Callohesma*. The seventh and eighth metasomal sterna (Figures 19–30) resemble those of some *Callohesma* species (Exley, 1974, Figures 5, 6).

### Taxonomy

Michener (1965) erected *Dasyhesma* for *D. robusta* known from nine females and one male from Western Australia. He recognised the similarity between *D. robusta* and a species described by Rayment (1935) and named *Euryglossimorpha abnormis*. It was known from one female also from Western Australia. Michener (1965) reclassified Rayment's species into a new subgenus *Dermatohesma* of the genus *Euryglossa* Smith. Subsequently, Michener (2000) synonymized the two taxa. He rejected *Dermatohesma* and selected *Dasyhesma* as the name of the genus now with two species *D. robusta* and *D. abnormis*.

It is now clear the genus contains many species and twenty-one are recorded in this paper. Their descriptions are not complete as males for many are unknown. Sex associations are primarily on collection data but many sites are close together and accuracy is not guaranteed.

### MATERIAL AND METHODS

Although the majority of specimens viewed are recently collected and beautifully set, some old specimens are in poor condition and often clogged with nectar and pollen. These I have included and named as they record the genus from different geographical areas.

Most specimens are females and the association of the males available is not always clear, so the key presented is for females alone.

In descriptions of species, 'relative head

measurements' express concisely the size relation between measurements on one head. Some descriptions are fuller than others but characters important for species recognition are always given.

Houston (2000) used code numbers for undescribed or unidentified bees in the Western Australian Museum that had been taken on wild flowers. When available on specimens these code numbers are given in the Remarks section of descriptions.

Descriptions were written after examination with a Wild stereomicroscope (Wild M5, Heerbrugg, Switzerland).

The following abbreviations have been used:

AM: Australian Museum, Sydney;

ANIC: Australian National Insect Collection, Canberra;

KU: Snow Entomological Collection, University of Kansas, Lawrence;

LAM: Natural History Museum of Los Angeles County;

QM: Queensland Museum;

RMBM: R.M. Bohart Museum of Entomology, University of California, Davis;

UQIC: University of Queensland Insect Collection, Brisbane;

WAM: Western Australian Museum, Perth;

T1, T2 etc.: metasomal terga 1, 2 etc.

S1, S2 etc.: metasomal sterna 1, 2 etc.

VP used in locations stands for "Vermin Proof" (Fence).

### Plant Associations

All except one species described here in which plant association is recorded were taken on flowers of the plant family Myrtaceae (usual for Euryglossinae). Females were found on the following genera: *Baeckea* (five species), *Scholtzia* (one species), *Chamelaucium* (one species) and *Verticordia* (nine species).

*Verticordia* is an Australian genus in which two species were shown to be almost certainly pollinated primarily by two bee species of the euryglossine genus *Euhesma* Michener (Houston, Lamont, Radford and Errington, 1993). Other species of *Verticordia* were subsequently widely sampled for bees by Dr Houston and this paper is one result. Female *Dasyhesma* bees on different species of *Verticordia* are distinct and are here described as separate species.

There are about 100 species in this entirely Australian plant genus found mostly in the south-west botanical province of Western Australia where spectacular displays are formed in spring and summer often in a mass of one colour.

*Verticordia* was divided by George (1991) into three subgenera on the basis of plant morphology. The two *Euhesma* bees mentioned above were associated with plants in the subgenus *Chrysoma* in

which the form of the flower is least complex. All the plants associated below with *Dasyhesma* bees are in the subgenus *Eperephes* where flowers are more complex and all but one are in the section considered most complicated of all.

Whether *Dasyhesma* bees play a role in pollination is unknown. The specific names chosen for many of the new species reflect their close association with particular plants.

## Genus *Dasyhesma* Michener

### Type Species

*Dasyhesma robusta* Michener, 1965: by original designation.

The following description relates to members of the genus. It expands the diagnosis in Michener (2000).

### Description

#### Female

Length 6–9 mm; head and thorax, dark brown or black, strongly punctate; propodeum black, in profile subvertical with narrow sloping upper zone; propodeal triangle granular; metasoma predominately black or red or orange; antennal bases above middle of face; pedicel longer than first flagellar segment; eyes converging below; fronto-clypeal suture often absent; mandible with broad, subapical tooth; labial palps with segment 2 smallest; segments 1, 3, and 4 usually about equal; facial foveae linear, often broad or partially expanded, less than 0.5 length of eye; sides of pronotum in front of lobes shining, often impunctate; basitibial plate open at apex; inner hind tibial spur pectinate; forewing (Figure 2) with costal margin of marginal cell at least 1.5 x length of pterostigma; second submarginal cell more than half as long as first, strongly narrowed towards marginal cell, macrotrichia on whole of wing; foveae of second tergum of metasoma shallow; metasomal terga dull, with dense, fine punctation; longitudinal median groove on T<sub>1</sub> ends dorsally in a sharp "shelf" seen in profile.

#### Male

Head and thorax black, strongly punctate; eyes converging below; antennae long, pedicel longer than first flagellar segment, middle flagellar segments about as long as wide; propodeum black; metasomal terga with fine, dense punctation, T7 with larger punctures and an impunctate median longitudinal ridge. Genitalia and hidden sterna Figures 16–34.

Two size groups occur among both sexes: in females, long (about 8 mm) and short (6.5–7 mm). Although fewer males are available and there is no

certainty about identification, it seems as though very small males are associated with short females. One feature of the genus is the relative similarity of the sexes – not common among Euryglossinae.

The genus can be divided into two main groups:

Group 1:

Females

Robust, stocky bees in which the head is wider than long (Figure 1), with antennae short with all flagellar segments except last wider than long; labrum oval; underside of prementum partly roughened; in many virtually no interspace between punctures on mesoscutum; tarsal claws with small tooth beyond middle (Figure 14); pterostigma nearly parallel-sided before base of vein r (Figure 2); fore tibial spur with malus not serrate; foretarsi with specialised setae; in dorsal view of most basitarsus margined anteriorly with flattened simple setae, posteriorly with pothook setae; segments 2, 3, 4 each with a set of long pothook setae posteriorly and much shorter set of simple setae anteriorly.

Males

Genitalia with penis valves extended distally (Figures 16, 17); S8 with shaft not expanded and shoulders with setae (Figures 19, 20).

Species included: *D. abnormis*, *D. albula*, *D. aurea*, *D. baekkea*, *D. boharti*, *D. brevipalpa*, *D. coolgardensis*, *D. dilata*, *D. scholtziae*.

Group 2:

Females

More slender bees with heads that appear longer than wide due to elongation of clypeus and eyes and sometimes malar area (Figure 3); antennae longer with middle flagellar segments almost as long as wide; labrum triangular; underside of prementum polished, not roughened; polished interspaces separate punctures on scutum; tarsal claws with a large diverging inner tooth and outer ramus forming a right angle (Figure 13); sides of pterostigma not quite so nearly parallel sided before base of vein r; fore tibial spur with malus serrate (Figure 15); foretarsi more hairy than in Group 1. Basitarsi with thick, somewhat flattened simple setae ventrally; segments 2–5 with very numerous curly pothook setae ventrally; all segments with very long apparently simple setae often forming a tangle dorsally.

Males

If large (6–7mm), genitalia with penis valves not extended distally (Figure 18); S8 with shaft expanded and shoulders without setae (Figures 21, 22).

Species included: *D. areola*; *D. depressa*, *D. forrestii*, *D. galbina*, *D. muelleriana*, *D. robusta*, *D. simulata*, *D. spicata*, *D. syntoma*.

Three species in which males associated on collection data are smaller (4–5mm) possess different terminalia. On whole specimens a small distal end of S8 is visible (cf. Figures 24, 25, 32 with Figures 19–23.). On dissection the genitalia may not show a gonocoxite projection (Figure 31); S7 has two elongate distal lobes heavily coated with plumed setae outside (Figures 26, 27). The lobes may curl under so the setae appear also on the inner side (Figure 26); the shaft of S8 is long and narrow (Figures 24, 25). Its strong curvature (Figure 32) contrasts with S8 of Group 1 (Figure 34) and large males of Group 2 (Figure 33). In these species the propodeum is less completely vertical than in other *Dasyhesma* males and misidentification cannot be dismissed.

Species included: *D. argentea*, *D. clypeata*, *D. lepidophyllae*.

Key to Females of the Genus *Dasyhesma*

- 1 Head as wide as thorax with antennae short and all flagellar segments except last wider than long [Group 1] ..... 2
- Head narrower than thorax with middle flagellar segments of antennae almost as long as wide [Group 2] ..... 10
- 2(1) Metasoma predominantly black with posterior margins of terga pale and translucent ..... 3
- Metasoma predominantly orange/yellow .. 5
- 3(2) Mesonotum with punctures very close with essentially no interspaces ..... 4
- Mesonotum with punctures separated by more than diameter of one puncture .....  
..... *D. dilata*, sp. nov.
- 4(3) Setae on T<sub>5</sub> and T<sub>6</sub> black; vertex lateral to median ocellus raised and impunctate ....  
..... *D. scholtziae* sp. nov.
- Setae on T<sub>5</sub> and T<sub>6</sub> golden; vertex not so raised and impunctate .....  
..... *D. abnormis* (Rayment)
- 5(2) Metasoma foveae black ..... 6
- Metasoma foveae reddish-orange ..... 8
- 6(5) Length about 9mm; mesonotum with punctures virtually touching .....  
..... *D. aurea*, sp. nov.
- Length about 8mm; mesonotum with punctures separated by at least diameter of one puncture ..... 7
- 7(6) Pronotal lobe black; facial foveae not curved towards lateral ocelli, widest below .....  
..... *D. boharti*, sp. nov.

- Pronotal lobe yellow posteriorly; facial foveae curved towards lateral ocelli, widest above ..... *D. coolgardensis*, sp. nov.
- 8(5) Length 8–9mm; mesonotum with punctures virtually touching ..... *D. albula*, sp. nov.  
Length 6.5–7mm; mesonotum with punctures separated by more than diameter of one puncture ..... 9
- 9(8) Clypeus densely punctured; labial palps small with segment 4 longer than segment 3; facial foveae reaching level of mid ocellus ..... *D. brevipalpa*, sp. nov.  
Clypeus sparsely punctured; labial palps with length of segments 3 & 4 about equal; facial foveae reaching level of lateral ocelli ..... *D. baeckea*, sp. nov.
- 10(1) Malar area distinct, about half as long as width of mandibular base; mandibles basally yellow-brown .....  
..... *D. robusta* Michener  
Malar area not obvious in most; mandibles basally black ..... 11
- 11(10) Anterior margin of clypeus markedly concave leaving large space between it and labrum (Figure 12) .....  
..... *D. areola*, sp. nov.  
Anterior margin of clypeus straight or slightly concave with at most small space between it and labrum (Figures 10, 11) ..  
..... 12
- 12(11) Clypeus and supraclypeal area concave in profile (Figure 7) ..... *D. depressa*, sp. nov.  
Clypeus and supraclypeal area not concave in profile ..... 13
- 13(12) All legs orange; labial palps with last three (3) segments pale yellow; antennal pedicel yellowish ..... *D. galbina*, sp. nov.  
All legs not orange; labial palps with last three (3) segments not pale yellow; antennal pedicel not yellowish ..... 14
- 14(13) Legs 2 and 3 orange ..... 15  
Legs 2 and 3 not orange ..... 17
- 15(14) Length about 8mm; labial palps with last two (2) segments pale yellow; all tarsal segments of legs 2 and 3 orange .....  
..... *D. simulata*, sp. nov.  
Length about 7mm; labial palps black or dark brown; last tarsal segment of legs 2 and 3 black/dark brown ..... 16
- 16(15) Fore legs with tibiae yellow dorsally; labrum yellowish brown .....  
..... *D. syntoma*, sp. nov.
- Fore legs black with only very base of tibiae yellowish; labrum black .*D. lepidophyllae* sp. nov.
- 17(14) Genal area not visible below anterior part of eye when viewed from side (Figure 9) ...  
..... 18  
Genal area clearly visible below anterior part of eye when viewed from side (Figure 5) ..... 19
- 18(17) Pterostigma yellow, opaque, margined with dark brown; body length about 7mm .....  
..... *D. muelleriana*, sp. nov.  
Pterostigma transparent, not yellow, margined with dark brown; body length less than 7mm ..... *D. argentea*, sp. nov.
- 19(17) Viewed from the side, head and mesosoma fringed with long white setae .....  
..... *D. forrestii*, sp. nov.  
Viewed from the side, head and mesosoma not fringed with long white setae ..... 20
- 20(19) Mid legs black ..... *D. clypeata*, sp. nov.  
Mid legs with tibiae and tarsi orange .....  
..... *D. spicata*, sp. nov.

#### GROUP 1

Females of three (3) species have the metasoma dark red/black with posterior margins of terga pale and translucent. They can be separated by the sculpture of the vertex and mesonotum.

The metasoma of females of the other six species described below is predominantly orange. Two of these are large (about 9mm long) and distinguished easily on colour characters. Males associated with one are also large. Males are associated with only one of the species with shorter females and they too are small. None of the species was recorded on *Verticordia*.

#### *Dasyhesma abnormis* (Rayment)

*Euryglossimorpha abnormis* Rayment, 1935: 664–5

*Euryglossa* (*Dermatohesma*) *abnormis* (Rayment) Michener, 1965: 91–92

*Dasyhesma abnormis* (Rayment) Michener, 2000: 215

#### Type

**Western Australia:** holotype ♀; Gngangara, December, B.A. O'Connor (ANIC).

Both the head and metasoma have been glued to a broken mesosoma. The right foreleg is the only complete leg.

#### Additional Material Examined

**Western Australia:** 2♀, 5.8km SE of Cataby, 8

January 1983, C.A. Howard and T.F. Houston, on flowers of *Baeckea* (WAM).

## Description

### Female

See Michener (1965) pp.91–92 for full description.

Length about 8.0mm; wing length about 5.5mm. Relative head measurements: width 7.1; length 6.3; eye length 4.6; lower interocular distance 3.8; upper interocular distance 4.7; clypeo-antennal distance 1.0; interantennal distance 1.4; antennocular distance 1.1; interocellar distance 1.3; ocellular distance 1.2.

The clypeus on the Cataby specimens is larger and more shining than in the holotype. In both, however, the foveae of the metasoma are black, flat and wide (just over 2 x as long as wide). Setae on  $T_5$  and  $T_6$  are golden.

### *Dasyhesma albula* sp. nov.

Figures 2, 14

### Types

**Western Australia:** holotype ♀, 54km, 27°E of N from Kalbarri on VP Fence, 27°16'02"S, 114°25'15"E, 19 November 1998, T.F. Houston, on flowers of *Baeckea blackallii* (WAM). Paratypes: **Western Australia:** 4♀, same data as holotype (WAM).

### Additional Material Examined

**Western Australia:** 4♀, 13km S of Wannoo (26.49 S, 114.37E), 24 October 1996, T.F. Houston, on flowers of *Thryptomene strongylophylla* (WAM).

## Description

### Female

Length about 9.0mm; wing length about 5.0mm. Relative head measurements: width 6.8; length 5.6; eye length 4.6; lower interocular distance 3.3; upper interocular distance 4.5; clypeo-antennal distance 0.7; interantennal distance 1.1; antennocular distance 1.1; interocellar distance 1.2; ocellular distance 1.2.

This large species is very similar to *D. aurea*. Most clear distinctions relate to colour – whereas all setae on *D. aurea* are long and golden, on *D. albula* they are white. The metasomal foveae of *D. albula* are very difficult to distinguish being of similar colour to the metasoma (orange). They are flat, about 3 x as long as wide. In *D. aurea*, these foveae are black.

Punctuation of the supraclypeal area and paraclypeal areas is more dense than in *D. aurea* and there are differences in the wing venation of the forewings particularly in the size of the second sub-marginal cell.

## Remarks

Code numbers in Houston (2000): F 306

## Etymology

The specific name is from the Latin and refers to the white pubescence.

### *Dasyhesma aurea* sp. nov.

Figures 17, 19, 29, 34

## Types

**Western Australia:** holotype ♀, East Yuna Nature Reserve, 34km WNW Mullewa, 12–14 September 1987, T.F. Houston, ex. nest (WAM). Paratypes: **Western Australia:** 5♀, 1♂, same data as holotype; 2♂, same data on 23–24 September 1983, C and T. Houston, on foliage of *Acacia* (flowerless) (WAM); 12♀, same data as holotype except on flowers of *Baeckea*; 3♀, same data as holotype except 13–16.ix.1984, entering or leaving burrow in bare sand.

## Additional Material Examined

**Western Australia:** 8♀, 7♂, 5km 23°N of W from Eurardy HS; 27 August 1999, T.F. Houston, on flowers or hovering close to ground beneath flowers of *Jacksonia cupulifera* (Fabaceae); 5♀, Denham-Hamelin Rd, 14km NW Tamala turnoff, 28 August 1997, T.F. Houston and P. Mathiasen, on flowers of *Malleostemon roseus* (WAM).

## Description

### Female

Length about 9.0mm; wing length about 5.5mm. Relative head measurements: width 6.8; length 5.5; eye length 4.5; lower interocular distance 3.6; upper interocular distance 4.5; clypeo-antennal distance 0.5; interantennal distance 1.0; antennocular distance 1.0; interocellar distance 1.2; ocellular distance 1.1.

Clypeus seen from the side gently convex; facial foveae broad, reaching level of lateral ocelli, basitibial plate margined by two carinae; inner hind tibial spur with 4–5 teeth; metasomal foveae flat, black, about 3 x as long as wide.

Head and mesosoma black with antennal flagellar segments 3–10 yellow ventrally; metasoma yellow/orange with black infuscation especially on  $T_1$ ; fore legs dark brown with tibiae yellowish dorsally; mid and hind legs yellow/orange; forewings with veins and pterostigma brown; head including upper half of clypeus heavily punctured, mesonotum very heavily punctured. Pubescence golden.

### Male

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 5.7; length 4.5; eye length 3.6; lower interocular distance 2.7; upper

interocular distance 3.8; interantennal distance 0.9; antennocular distance 0.8; interocellar distance 1.1; ocellocular distance 1.0.

Most obvious feature is the heavy pubescence – longer on the mesonotum and legs than on ventral thorax, also more on metasomal dorsum than in other species. Hairs on vertex and dorsal body surface slightly golden, on lower face and genae, and ventral body surface, white. Head and mesosoma black, metasoma dark brown. Legs dark brown with distal ends of femora and tibiae and tarsi partially yellow.

Genitalia: Figure 17.

Seventh metasomal sternum: Figures 29, 34.

Eighth metasomal sternum: Figure 19.

#### Remarks

Code numbers in Houston (2000): F300/M264.

#### Etymology

The specific name is from the Latin and refers to the golden pubescence especially of the female. This clearly distinguishes this species from *D. albula*.

#### *Dasyhesma baeckea* sp. nov.

Figure 1

#### Types

**Western Australia:** holotype ♀, 10km WNW of Eurardy HS 27°32'18"S, 114°34'54"E, 21–24 October 1998, T.F. Houston and O. Mueller, on flowers of *Baeckea* (WAM). Paratypes: **Western Australia:** 9♀, same data as holotype (WAM).

#### Additional Material Examined

**Western Australia:** 1♀, 23km SE of Kalbarri, 29 October 1996, T.F. Houston, on flowers of *Baeckea* sp. (WAM)

#### Description

##### Female

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 6.1; length 5.1; eye length 4.0; lower interocular distance 3.2; upper interocular distance 3.9; clypeo-antennal distance 0.6; interantennal distance 1.1; antennocular distance 1.0; interocellar distance 1.0; ocellocular distance 0.9.

Clypeus gently convex seen from the side; facial foveae a polished trough as broad as base of scape, reaches level of lateral ocelli and turns in; basitibial plate indicated by anterior and posterior carinae; inner hind tibial spur with six (6) teeth; metasomal foveae about 2.5 x as long as wide, difficult to distinguish from surface of T<sub>2</sub>.

Head and mesosoma black with antennal flagellum yellowish ventrally, metasoma orange;

fore legs black with tip of femur, tibia and tarsi mostly orange; mid and hind legs orange with coxae and trochanters black; forewings with veins dark brown (R black), pterostigma yellow-orange; clypeus polished, lightly punctured, rest of head and mesosoma heavily punctured; propodeal triangle granular; long white hair on ventral body surface; T<sub>5</sub> with long, golden plumose setae on surface and posterior margin; similar hairs obscure surface of T<sub>6</sub>.

#### Remarks

Code numbers in Houston (2000): F400/F305?

#### Etymology

The specific name refers to the plant genus *Baeckea* from which five of the species here recorded were collected.

#### *Dasyhesma boharti* sp. nov.

#### Types

**Western Australia:** holotype ♀, Carrabin, 18 November 1979, R.M. Bohart (QM). Paratype: **Western Australia:** 1♀, same data as holotype (RMBM).

#### Description

##### Female

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 6.3; length 5.4; eye length 3.9; lower interocular distance 3.4; upper interocular distance 4.0; interantennal distance 1.1; antennocular distance 0.9; interocellar distance 1.1; ocellocular distance 1.0.

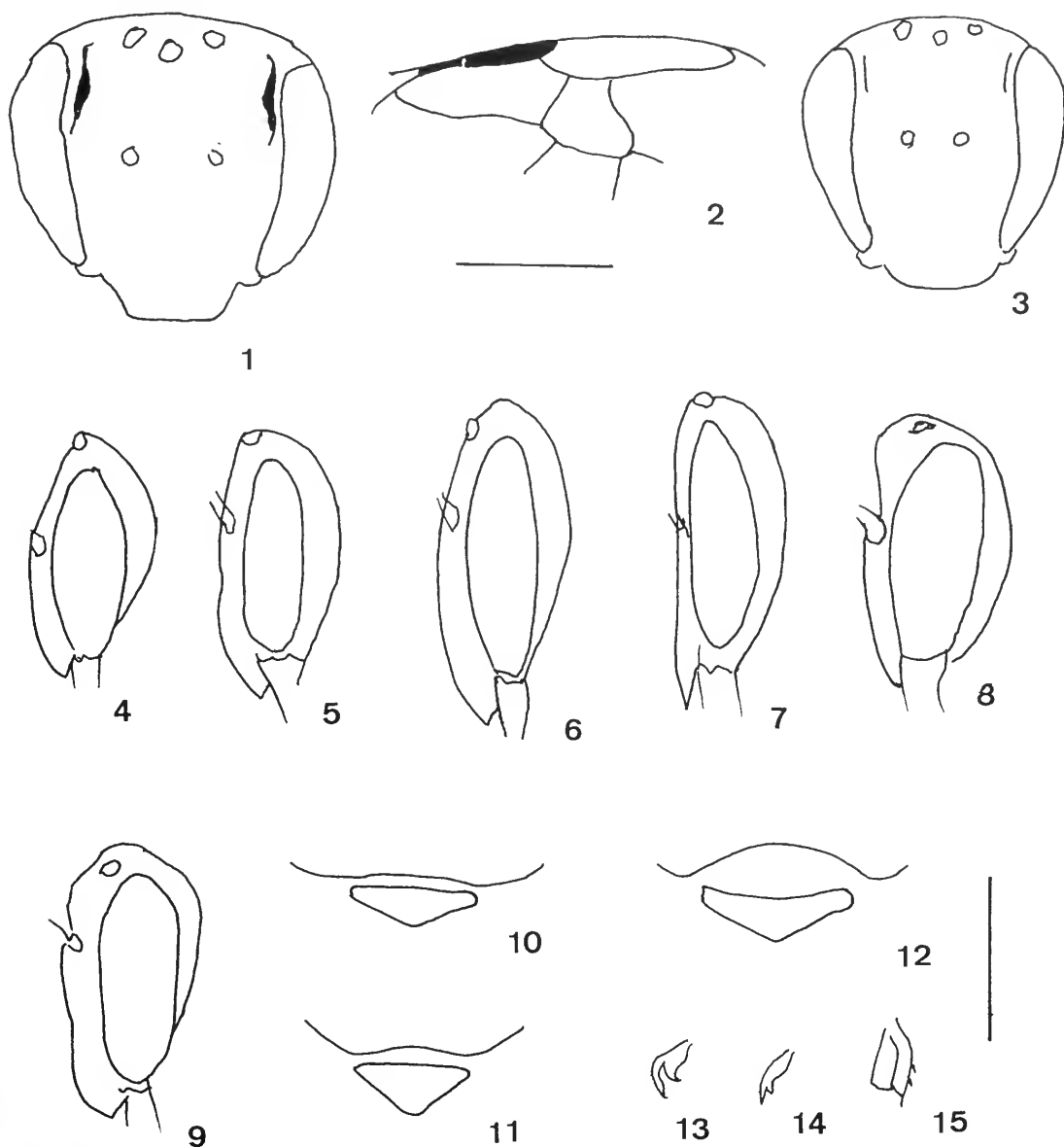
Clypeus gently convex seen from the side; facial foveae linear, wide, reaching level of lateral ocelli; basitibial plate margined by carinae; inner hind tibial spur with four teeth; metasomal foveae flat, black, 3 x as long as wide.

Head and mesosoma black with antennal flagellum yellowish ventrally; metasoma yellow-brown with black infuscations; forelegs brown with tibiae and tarsi orange; mid and hind legs orange; forewings with veins and pterostigma brown, clypeus with punctures less dense than on frons. Pubescence white, longer on ventral body surface and legs, most extensive and cream on metasomal segments 5 and 6 (dorsal and ventral).

#### Etymology

The specific name honours the collector Professor R.M. Bohart and the Museum of Entomology, University of California, Davis, United States of America, where I was able to study the bee collection in 1987.





Figures 1–15 Females of *Dasyhesma* spp. 1, 3: Heads of *D. baeckea* and *D. syntoma*. 2: Section of forewing of *D. albula*. 4–9: Side view of heads of *D. argentea*, *D. clypeata*, *D. areola*, *D. depressa*, *D. scholtziae*, *D. muelleriana*. 10–12: Anterior margin of clypeus and labrum of *D. clypeata*, *D. galbina*, *D. areola*. 13–14: Hind tarsal claws of *D. galbina*, *D. albula*. 15: Fore tibial spur of *D. forrestii*. Scale lines: 1–9 = 1mm; 10–15 = 0.5mm

*Dasyhesma brevipalpa* sp. nov.

Figures 23, 28

**Types**

**Western Australia:** holotype ♀, 13km N of Eurardy HS, 27°27'00"S, 114°41'17"E, 25 October 1998, T.F. Houston and O. Mueller, on flowers of *Baeckea* (Myrtaceae) (WAM). Paratypes: **Western Australia:** 3♀, same data as holotype (WAM).

**Additional Material Examined**

**Western Australia:** 2♂, 9km 10°N of W from Eurardy HS; 6 November 1999, T.F. Houston, flying near flowers of *Verticordia areola* and others; 8♀, 1♂, 9km NNE of Eurardy HS on NW Coastal Highway 25–28 October 1996, T.F. Houston on flowers of *Baeckea* sp.; 2♂, same data one on flowers of *Pileanthus* sp. other on or flying around flowers of *Chamelaucium oenanthem* (all in WAM).

## Description

### Female

Length about 6.5mm; wing length about 4.0mm. Relative head measurements: width 5.3; length 4.3; eye length 3.5; lower interocular distance 2.3; upper interocular distance 3.4; clypeo-antennal distance 0.4; interantennal distance 0.9; antennocular distance 0.9; interocellar distance 1.0; ocellocular distance 0.9.

Clypeus flattish medianly; facial foveae trough-like, widest medianly, reaching level of mid ocellus; labial palps very short with segments 2 and 3 about equal and 1 and 4 larger but about equal; basitibial plate with both carinae broken into tubercles; inner hind tibial spur with at least four large teeth; metasomal foveae about 3 x as long as wide, flat, light brown. Head and mesosoma black with antennal flagellum yellowish ventrally and mandibles black basally, then amber before red tips; fore and mid legs black with femora distally, tibiae and tarsi orange; hind legs orange; forewings with veins and margins of pterostigma dark brown, inside pterostigma yellowish; metasoma orange.

Head more densely punctured than central mesonotum. Pubescence white, longer on venter and legs, dense around antennal bases and pronotal lobes, very dense and cream on posterior margin of  $T_5$  and on  $T_6$ .

### Male

Length about 5.0mm; wing length about 3.0mm. Relative head measurements: width 4.3; length 3.5; eye length 2.8; lower interocular distance 2.0; upper interocular distance 3.0; interantennal distance 0.7; antennocular distance 0.5; interocellar distance 0.9; ocellocular distance 0.8.

The sexes are associated primarily on the basis of both having short labial palps. An obvious feature is the long white pubescence on the lower half of the face, ventral head, thorax and legs; forewings as in female; colours as in female with more brown on legs and metanotum dark brown with venter yellowish. Males can be recognised by short palps, yellow labrum and mandibles (except tip), yellowish venter and legs distally.

Seventh metasomal sternum: Figure 28.

Eighth metasomal sternum: Figure 23.

### Remarks

Code numbers in Houston (2000): F305/M268.

### Etymology

The specific name comprises two Latin words for short palps, characteristic of this species.

*Dasyhesma coolgardensis* sp. nov.

### Type

**Western Australia:** holotype ♀, 25 (ml) S, Coolgardie, 28 October 1958, E.F. Riek (ANIC).

### Description

#### Female

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 5.8; length 5.1; eye length 3.8; lower interocular distance 3.5; upper interocular distance 3.7; clypeo-antennal distance 0.7; interantennal distance 0.9; antennocular distance 1.0; interocellar distance 1.0; ocellocular distance 0.9.

Clypeus gently convex seen from the side; facial foveae with top greatly expanded and curved into lateral ocelli; basitibial plate margined on each side by a carina with terminal tubercle; inner hind tibial spur with at least four (4) teeth (not clearly visible); metasomal foveae flat, black, 3 x as long as wide.

Head and mesosoma black with antennal flagellum yellowish beneath; metasoma yellowish with black infuscations in middle of  $T_1$ ,  $T_2$ ,  $T_3$  and almost covering  $T_4$  and  $T_5$ ; legs predominantly yellow/orange with most segments showing some brown incursions and all tarsi virtually dark brown; forewings with veins and pterostigma brown; punctuation fairly uniform on head.

Pubescence plentiful and yellowish on head and mesosoma dorsally, longer and white ventrally and on legs; metasoma with long white setae ventrally, short dorsally except long and yellowish on  $T_5$ ,  $T_6$ .

### Remarks

The legs of the only specimen seen of this species exhibit characteristics of females of Group 2 – pretarsal claws with the outer ramus right angled and the inner ramus large and diverging. In addition, the pubescence of the foretarsi resembles that seen in Group 2.

### Etymology

The specific name reflects where it was collected – to date, the most easterly site for the genus.

*Dasyhesma dilata* sp. nov.

### Types

**Western Australia:** holotype ♀, 3.5–5.5km S of Yellodine (31°18'S, 119°39'E), 27 October 1978, T.F. Houston, on flowers of *Baeckea* ? *leptospermoides* (WAM). Paratypes: **Western Australia:** 2♂, same data as holotype (WAM).

### Description

#### Female

Length about 8.0mm; wing length about 5.0mm.

Relative head measurements: width 6.8; length 5.6; eye length 4.3; lower interocular distance 3.7; upper interocular distance 4.4; clypeo-antennal distance 0.5; interantennal distance 1.2; antennocular distance 1.2; interocellar distance 1.1; ocellocular distance 1.2.

Similar to other Group 1 species in which the metasoma is dark red/black with posterior margins of terga pale and translucent (i.e. *D. abnormis* and *D. scholtzia*). This species differs in the sculpture of the centre of the scutum where punctures are much farther apart (more than the diameter of one puncture). In the other species there is virtually no space between punctures.

#### Male

Length about 6.5mm; wing length about 4.5mm. Relative head measurements: width 5.4; length 4.3; eye length 3.2; lower interocular distance 2.8; upper interocular distance 4.5; interantennal distance 0.9; antennocular distance 0.7; interocellar distance 1.0; ocellocular distance 1.0.

Head and mesosoma black, metasoma black/dark brown dorsally, yellowish ventrally. Legs black/dark brown with ends of femora and most of tibiae and tarsi yellowish.

#### Remarks

This species is the only one of the three species of Group 1 in which the metasoma is predominantly black with interspace between the punctures of the mesonotum.

#### Etymology

The specific name is from the Latin and refers to the punctures of the middle of the mesoscutum which are not almost touching, they are 'spread out'.

#### *Dasyhesma scholtziae* sp. nov.

Figures 8, 16, 20

#### Types

**Western Australia:** holotype ♀, Melaleuca Park Nature Reserve, 12km NE Wanneroo, 12 January 1996, T. Houston and C. Boase, on or about white flowers of *Scholtzia* (Myrtaceae) (WAM). Paratypes: **Western Australia:** 4♂, same data as holotype; 2♀, Forrestdale Lake Reserve, 25km SSE Perth, 9 February 1996, T.F. Houston and C.K. Boase, on flowers of *Scholtzia* (WAM).

#### Additional Material Examined

**Western Australia:** 4♀, 6.5km SSE Regans Ford, 8 January 1983, C.A. Howard and T.F. Houston on flowers of *Scholtzia*; 1♀, Moore River National Park, 31 December 1989, T.F. Houston, on flowers of *Scholtzia*; 1♀, Bullsbrook, A. Douglas, number 46-2576 (WAM).

#### Description

##### Female

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 6.7; length 5.5; eye length 4.0; lower interocular distance 3.2; upper interocular distance 4.5; clypeo-antennal distance 0.6; interantennal distance 1.0; antennocular distance 1.0; interocellar distance 1.4; ocellocular distance 1.2.

Facial foveae about 0.25 x length of eye; genal area about 0.25 x width of eye seen from side; gastral foveae almost 4 x as long as wide; basitibial plate about 3.3 x length of hind tibia; inner hind tibial spur with 6–8 teeth; head with punctures closest on supraclypeal area; vertex lateral to median ocellus raised and almost impunctate; mesosoma with virtually no space between punctures; metasomal terga dull, minutely roughened without punctures.

Antennae black with flagellar segments yellow ventrally; legs dark brown with fore tibiae yellowish; metasoma dark brown/black with posterior margins of terga and sterna translucent.

Pubescence white, most abundant dorsally around antennal bases, as occipital fringe, on metanotum, sides of propodeum; long white setae on ventral body and legs; long dense black setae on  $T_5$ .

##### Male

Length about 5.5–6.0mm; wing length about 4.0mm. Relative head measurements: width 5.0; length 4.0; eye length 3.1; lower interocular distance 2.4; upper interocular distance 3.8; interantennal distance 0.9; antennocular distance 0.4; interocellar distance 1.2; ocellocular distance 1.0.

Colour as in female with more yellow on legs and antennal flagella with basal 4–6 segments entirely yellow.

Pubescence as in female with more long white setae on lower face and progressively longer fringe on posterior margins of  $S_3$ – $S_7$ .

#### Remarks

The raised, almost impunctate areas lateral to the median ocellus in both sexes have been seen nowhere else. Distinctive features of males also include the very strongly converging eyes and the bi-coloured antennae not viewed elsewhere.

The specimen in WAM from Bullsbrook was labelled a paratype of *D. robusta* by Michener.

Code numbers in Houston (2000): F303/M266.

#### Etymology

The specific name refers to the plant on which specimens were collected.

## GROUP 2

The metasoma of females of this group is predominantly orange/red or brown. In *D. robusta*, the type species of the genus, the metasoma of some specimens is predominantly dark red/black with posterior margins of terga pale and translucent as in three species of Group 1.

Except for *D. clypeata* (found on *Chamelaucium* sp.) and *D. robusta* (no record), all species in this group were taken on *Verticordia* spp. with a different bee species on each *Verticordia* species. This of course suggests they might play a role in pollination. An exception occurred however in *V. dichroma* on which three *Dasyhesma* species were recorded. Two with similar conspicuously lengthened labial palps were on separate varieties *V. dichroma dichroma* and *V. dichroma syntoma*. The third species also occurred on the latter.

### *Dasyhesma areola* sp. nov.

Figures 6, 12, 21

#### Types

**Western Australia:** holotype ♀, 9km 10°N of W from Eurardy HS, 27°32'53"S, 114°34'57"E, 6 November 1999, T.F. Houston, on flowers of *Verticordia areola* (WAM). Paratypes: **Western Australia:** 5♀, same data as holotype; 2♂, same data, flying near flowers of *Verticordia areola* and others (WAM, ANIC, UQIC).

#### Additional Material Examined

**Western Australia:** 2♀, 13km 35°S of W from Eurardy HS; 2♀, 1♂, 56km 33°E of N from Kalbarri on VP Fence, 28 October 1998, T.F. Houston and O. Mueller, on flowers of *Verticordia areola* (WAM).

#### Description

##### Female

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 5.3; length 5.1; eye length 4.2; lower interocular distance 2.8; upper interocular distance 3.3; interantennal distance 0.5; antennocular distance 0.8; interocellar distance 1.0; ocellocular distance 0.7; labrum length 0.5; 3.5–4 x as wide as long.

Anterior margin of clypeus concave, in all specimens seen separated from labrum creating a space about the size of the labrum (Figure 12); genal area seen from the side almost absent behind anterior third of eye (Figure 6); basitibial plate margined by carinae with three tubercles at end of posterior carina; inner hind tibial spur with 5 teeth; foveae of second tergum of metasoma not evident.

Head and mesosoma black with last seven antennal flagellar segments brown ventrally; forelegs black; midlegs with coxa, trochanter and

femur black, remainder orange with black infusions; hind leg yellow-orange; metasoma yellow-orange with dark incursions on segments 1–3 in some.

##### Male

Length about 7.0mm; wing length about 4.5mm. Relative head measurements: width 4.5; length 4.5; eye length 3.5; lower interocular distance 2.4; upper interocular distance 2.8; interantennal distance 0.3; antennocular distance 0.8; interocellar distance 0.8; ocellocular distance 0.8; labrum length 0.2.

Space between labrum and clypeus as in female; gena as in female.

Head and mesosoma black, legs and metasoma dark brown.

Eighth metasomal sternum : Figure 21.

#### Remarks

Code numbers in Houston (2000): F398/M363.

#### Etymology

The specific name is from a Latin word for small space, and refers to the separation of the labrum from the clypeus. It is also the name of the species of *Verticordia* on which all specimens were collected.

### *Dasyhesma argentea* sp. nov.

Figure 4, 31, 32

#### Types

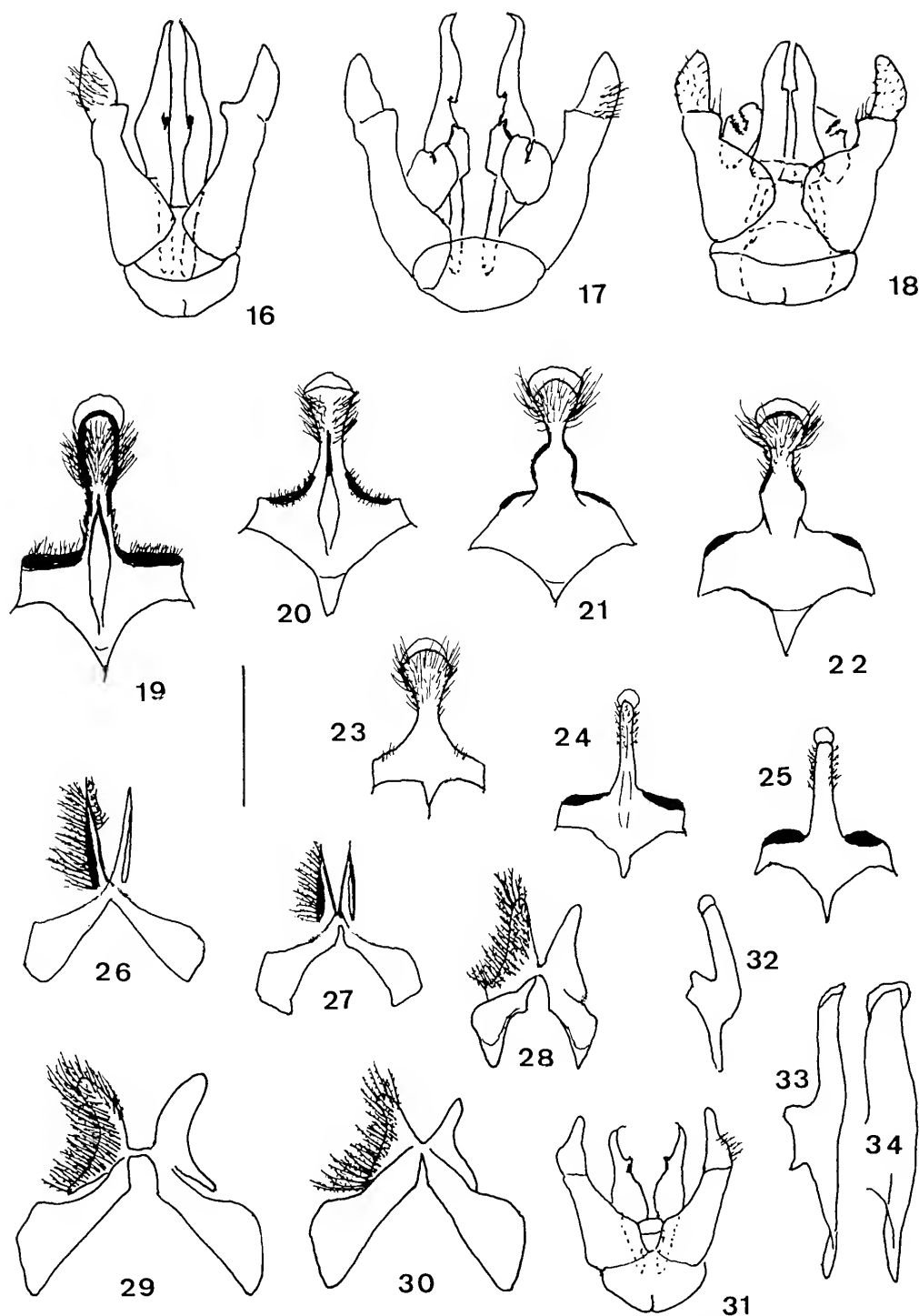
**Western Australia:** holotype ♀, 10.5km S Eneabba (29°49'S, 115°16'E), 3–4 November 1992, T.F. Houston, on flowers of *Verticordia argentea* (WAM). Paratypes: **Western Australia:** 5♀, 2♂ same data as holotype (WAM, ANIC, UQIC).

#### Description

##### Female

Length about 6.5mm; wing length about 4.0mm. Relative head measurements: width 4.4; length 4.6; eye length 3.3; lower interocular distance 2.5; upper interocular distance 3.0; interantennal distance 0.5; antennocular distance 0.6; interocellar distance 1.0; ocellocular distance 0.6; labrum length 0.3, about 2.75 x as wide as long.

Facial foveae curving faintly towards lateral ocelli; genal area not visible from side behind anterior part of eye; gastral foveae about 4 x as long as wide; inner hind tibial spur with 6–7 teeth; head and mesosoma black, antennal flagellum with segments 4–10 yellowish ventrally; legs dark brown with spot of yellow on base of fore tibia; metasoma orange/brown; veins and margins of pterostigma dark brown; long white setae on mesosoma, legs, venter; long golden setae on  $T_5$ ,  $T_6$ ,  $S_6$ . Punctuation most dense on frons.



Figures 16–34 Males of *Dasyhesma* spp. Scale line = 0.5 mm. 16–18 Genitalia. 16 *D. scholtziae* dorsal view; 17 *D. aurea* ventral view; 18 *D. simulata* dorsal view. 19–25 Eighth metasomal sternum Ventral view: 19 *D. aurea*; 20 *D. scholtziae*; 21 *D. arcola*; 22 *D. simulata*; 23 *D. brevipalpa*; 24 *D. lepidophyllae*; 25 *D. clypeata*. 26–30 Seventh metasomal sternum Ventral view: 26 *D. clypeata*; 27 *D. lepidophyllae*; 28 *D. brevipalpa*; 29 *D. aurea*; 30 *D. simulata*. 31 Genitalia *D. argentea*. 32–34 Seventh metasomal sternum Side view: 32 *D. argentea*; 33 *D. galbina*; 34 *D. aurea*

*Male*

Length about 4.0mm; wing length about 3.5mm. Relative head measurements: width 3.5; length 3.7; eye length 2.5; lower interocular distance 1.9; upper interocular distance 2.2; interantennal distance 0.5; antennocular distance 0.4; interocellar distance 0.7; ocellocular distance 0.6.

Colour black with on distal half of each femur a streak of yellow dorsally.

Genitalia: Figure 31.

Seventh metasomal sternum: Figure 32.

**Remarks**

The male terminalia are similar to Figures 24–27 and raise doubts about the accuracy of the sex association.

**Etymology**

The specific name is taken from the species of *Verticordia* on which the bees were caught.

*Dasyhesma clypeata* sp. nov.

Figures 5, 10, 25, 26

**Types**

**Western Australia:** holotype ♀, Bungabandi Ck, 16.5km 40°N of W from Eurardy HS, 27°28'25"S, 114°32'58"E, 5 November 1999, T.F. Houston, on flowers of *Chamelaucium oenanthum* (WAM). Paratypes: **Western Australia:** 8♀, same data as holotype (WAM, ANIC, UQIC).

**Additional Material Examined**

**Western Australia:** 3♀, 24♂, 9km NNE of Eurardy HS on NW Coastal Highway, 25–28 October 1996, T.F. Houston, on or flying around flowers of *Chamelaucium oenanthum* (WAM).

**Description***Female*

Length about 7.0mm; wing length about 4.5mm. Relative head measurements: width 5.0; length 5.2; eye length 3.7; lower interocular distance 3.0; upper interocular distance 3.3; interantennal distance 0.8; antennocular distance 0.9; interocellar distance 1.1; ocellocular distance 0.8; labrum length 0.3, about 3.3 x as wide as long.

Clypeus viewed from the side strongly convex from the level of anterior end of eyes; facial foveae linear, curving towards lateral ocelli; basitibial plate margined by carinae and tubercles; inner hind tibial spur with 6–7 teeth; metasomal foveae shallow groove, about 5 x as long as wide.

Head including mouthparts and mesosoma very black with tips of mandibles red and last 7 antennal flagellar segments conspicuously yellow ventrally; metasoma orange with black infuscations; fore and

mid legs black, hind legs orange; forewings with veins and margins of pterostigma dark brown; apex of marginal cell separated from wing margin by about 2 vein widths; clypeus very highly polished, not heavily punctured. Long white hairs on leg bases, ventral body surface; extensive golden pubescence on  $T_5$ ,  $T_6$  and  $S_6$ .

*Male*

In the presumed males of this species the propodeal triangle is covered with small punctures and its horizontal portion is larger than elsewhere in the genus.

Length about 5.0mm; wing length about 3.0mm. Relative head measurements: width 3.8; length 4.6; eye length 3.6; lower interocular distance 2.0; upper interocular distance 2.6; interantennal distance 0.6; antennocular distance 0.5; interocellar distance 0.8; ocellocular distance 0.6; labrum not triangular, length 0.2.

Colour black with antennal flagellar segments yellow ventrally and all legs with all coxae and trochanters black and femora distally, fore tibiae dorsally, mid and hind tibiae ventrally and all tarsi yellowish.

The clypeus although heavily obscured by long white setae is curved as in the female.

Seventh metasomal sternum: Figure 26.

Eighth metasomal sternum: Figure 25.

**Remarks**

The male propodeum and terminalia raise doubts about the sex association.

**Etymology**

The specific name is from the Latin and draws attention to the large, black, curved, polished clypeus of the female: the 'shield'.

*Dasyhesma depressa* sp. nov.

Figure 7

**Types**

**Western Australia:** holotype ♀, Red Bluff, 6 November 1971, D.N. McFarland, (ANIC). Paratypes: **Western Australia:** 2♀, same data as holotype (ANIC, UQIC).

According to my gazetteer, there are at least five Red Bluffs in Western Australia but Dr Houston (WAM) considers just south of the Kalbarri township the likely site as the collector was known to visit in that area.

**Description***Female*

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 5.4; length 5.6;

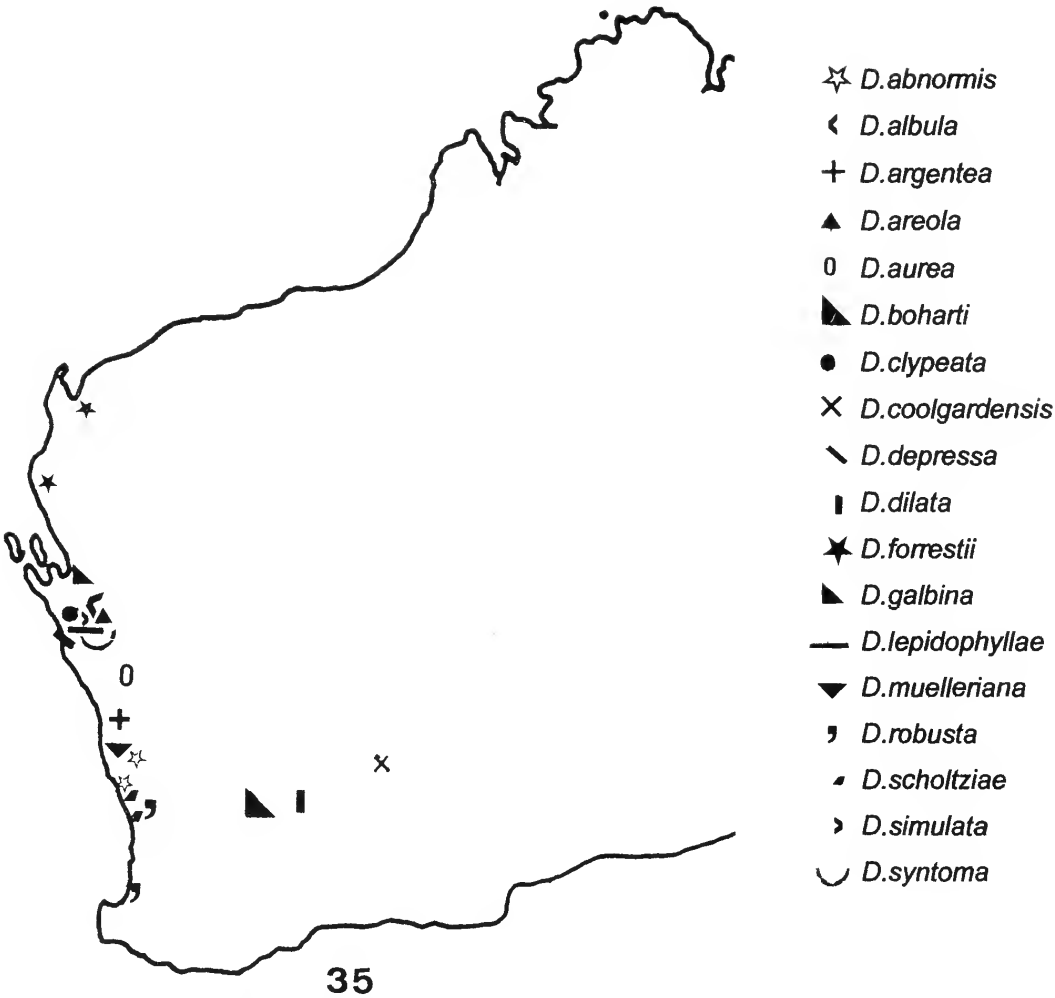


Figure 35 Known distribution of some bees of the genus *Dasyhesma*.

eye length 4.2; lower interocular distance 3.5; upper interocular distance 3.7; interantennal distance 1.0; antennocular distance 0.9; interocellar distance 1.2; ocellocular distance 1.0; labrum length 0.4; labial palp segment one longest; genal area narrower than eye seen from the side; malar space clearly evident; basitibial plate delineated by posterior carina only; inner hind tibial spur with 3–5 teeth; foveae of second tergum of metasoma about 6 x as long as wide; black in holotype.

Head, mesosoma and legs 1 and 2 black; leg 3 orange; metasoma yellow-orange marked with black (in holotype, anterior half of terga 1–3 is black).

Head and mesosoma very highly polished, not heavily punctured. Clypeus flat and supraclypeal area depressed resulting in a hollow in the middle of the face. Some long white setae on ventral body and base of legs, long cream setae on  $T_5$ ,  $T_6$ .

Remarks

This species is quite different from others in Group 2. In addition to the characters mentioned, setae on the foretarsi resemble those on females of Group 1 and the tarsal claws are smaller, outer ramus not very right-angled and with no tooth visible on fore legs.

Etymology

The specific name is from the Latin and refers to the ‘pressed down’ appearance of the middle of the face.

*Dasyhesma forrestii* sp. nov.

Figure 15

Types

Western Australia: holotype ♀, 7km N of

Boologoor HS (24°39'S, 113°42'E), 27–29 August 1980, C.A. Howard and T.F. Houston, on flowers of *Verticordia forrestii* (WAM). Paratypes: **Western Australia**: 1♀, 7♂, same data as holotype (WAM).

#### Additional Material Examined

**Western Australia**: 2♀, 16km WSW Yannarie River Xing, NW Coastal Highway, 30 September 1997, T.F. Houston and P. Mathiasen, on flowers of *Verticordia forrestii*; 8♀, 121mi NNE of Carnarvon, 22 August 1971, T.F. Houston, on *Verticordia* (WAM).

#### Description

##### Female

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 5.5; length 5.3; eye length 4.1; lower interocular distance 3.0; upper interocular distance 3.6; interantennal distance 0.7; antennocular distance 0.9; interocellar distance 1.1; ocellocular distance 1.0; length of labrum 0.4, about 2.75 x as wide as long.

Genal area narrower than eye seen from the side; basitibial plate indicated by a carina and tubercle posteriorly and short anterior carina; inner hind tibial spur with 4–5 teeth; foveae of second tergum of metasoma 4 x as long as wide, dark brown.

Head and mesosoma black; legs brown with both ends of all tibiae yellowish; metasoma very variable orange brown with areas of black.

Longish white hair on head, mesosoma, ventral metasoma with dense cream setae on T<sub>5</sub> and T<sub>6</sub>.

##### Male

Length about 6.0mm; wing length about 5.0mm. Relative head measurements: width 4.7; length 4.4; eye length 3.4; lower interocular distance 2.0; upper interocular distance 3.0; interantennal distance 0.6; antennocular distance 0.6; interocellar distance 0.9; ocellocular distance 0.6; length of labrum 0.2, about 4.5 x as wide as long.

Head and mesosoma black, metasoma dark brown; antennae black with flagellum light brown ventrally, legs dark brown with yellowish tarsi and knees, plentiful long white hair on head, mesosoma, legs and ventral metasoma.

#### Remarks

Code numbers in Houston (2000): F301/M265.

#### Etymology

The specific name is taken from the species of *Verticordia* on which most specimens were taken.

*Dasyhesma galbina* sp. nov.

Figures 11, 13, 33

#### Description

##### Types

**Western Australia**: holotype ♀, 13km S of Wannoo (26°49'S, 114°37'E), 24 October 1996, T.F. Houston, on flowers of *Verticordia dichroma* var. *syntoma* (Myrtaceae) (WAM). Paratypes: **Western Australia**: 3♀, 6♂, same data as holotype (WAM, ANIC, UQIC).

#### Additional Material Examined

**Western Australia**: 1♀, 51km, 17°E of N from Kalbarri on VP Fence, 16–19 November 1998, T.F. Houston, on flowers of *Verticordia dichroma* var. *syntoma* (WAM).

#### Description

##### Female

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 5.1; length 5.1; eye length 3.9; lower interocular distance 2.5; upper interocular distance 3.3; interantennal distance 0.5; antennocular distance 0.8; interocellar distance 0.9; ocellocular distance 0.7; labrum length 0.5, about 2 x as wide as long, margined by setae longer than mid (greatest) length of labrum; genal area less than half width of eye seen from side, almost invisible below anterior third of eye; basitibial plate indicated by anterior and posterior carinae with one or two tubercles at end of latter, less than half length of hind tibia; inner hind tibial spur with 5–7 teeth; foveae of second tergum of metasoma shallow, about 3 x as long as wide, difficult to distinguish.

Head and mesosoma black with terminal segments of labial (2–4) and maxillary palps (4–6) pale yellow, remaining segments dark brown; antennae black with pedicel and flagellar segments 4–10 yellow ventrally; metasoma and legs except fore coxae which are black, yellow/orange.

##### Male

Length about 6.0mm; wing length about 4.0mm. Relative head measurements: width 4.4; length 4.5; eye length 3.2; lower interocular distance 2.1; upper interocular distance 3.0; interantennal distance 0.5; antennocular distance 0.6; interocellar distance 0.9; ocellocular distance 0.7; labrum length 0.3, about 3 x as wide as long.

Head and mesosoma black/dark brown with antennal flagellar segments yellowish below; labial and maxillary palps dark brown; legs dark brown with ends of all femora, at least the inner surface of tibiae and all tarsi yellow; metasoma dark brown with T<sub>7</sub> yellowish.

Seventh metasomal sternum: Figure 33.



### Etymology

The specific name is from the Latin meaning yellowish in reference to the colour of the terminal segments of the palps, parts of the antennae and all legs of the female.

#### *Dasyhesma lepidophyllae* sp. nov.

Figures 24, 27

### Types

**Western Australia:** holotype ♀, 51km 17°E of N from Kalbarri on VP Fence, 27°15'22"S, 114°19'58"E, 25–27 October 1998, T.F. Houston and O. Mueller, on flowers of *Verticordia lepidophylla* var. *quantula* (Myrtaceae) (WAM). Paratypes: **Western Australia:** 6♀, same data as holotype (WAM, UQIC).

### Additional Material Examined

**Western Australia:** 1♀, Bungabandi Ck, 19km 38° N of W from Eurardy HS, 9 November 1999, T.F. Houston on flowers of *Verticordia lepidophylla* var. *lepidophylla*; 2♂, same data except 'flying near flowers' at 16.5km 40°N of W from Eurardy HS (WAM); 2♀, 10km N of Binu 23 November 1988, R.A. Snelling and J. Gray on flowers of *Grevillea* sp (Proteaceae) (LAM).

### Description

#### Female

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 5.3; length 4.9; eye length 3.8; lower interocular distance 2.7; upper interocular distance 3.4; interantennal distance 1.0; antennocular distance 0.8; interocellar distance 1.3; ocellocular distance 0.8; labrum length 0.3, about 3.3 x as wide as long.

Genal area very narrow under anterior half of eye when seen from side; inner hind tibial spur with 3–4 teeth; gastral foveae difficult to see, about 4 x as long as wide.

Head black with antennal flagellar segments 4–10 yellowish ventrally; mesosoma black; fore legs black with base of tibiae yellowish; mid and hind legs orange with last tarsal segment black/dark brown.

Clypeus with fewest punctures; clypeus and propodeal triangle highly polished; long white hairs on ventral body, shorter on tops of head and thorax, long golden setae on  $T_5$ ,  $T_6$ .

#### Male

Length about 4.5mm; wing length about 3.5mm. Relative head measurements: width 3.7; length 3.7; eye length 2.6; lower interocular distance 1.8; upper interocular distance 2.5; interantennal distance 0.6; antennocular distance 0.4; interocellar distance 1.0; ocellocular distance 0.6; labrum not triangular, length about 0.1, 6 x as wide as long.

Head black with underside of antennal flagellum yellowish; mesosoma black, legs black with all femora apically, fore tibiae dorsally and first tarsal segments yellowish; metasoma dark brown. Long white setae on head, mesosoma and legs.

Seventh metasomal sternum: Figure 27.

Eighth metasomal sternum: Figure 24.

### Remarks

The male terminalia raise doubts about the sex association. The two specimens in LAM are the only records of females not on Myrtaceae.

Code number in Houston(2000): F399.

### Etymology

The specific name refers to the species of *Verticordia* on which the type specimens were found.

#### *Dasyhesma muelleriana* sp. nov.

Figure 9

### Types

**Western Australia:** holotype ♀, Watheroo National Park (N.W. Corner), 30°11'S, 115°44'E, 15–16 November 1997, T.F. Houston, on flowers of *Verticordia muelleriana muelleriana* (Myrtaceae) (WAM). Paratypes: **Western Australia:** 2♀, same data as holotype (WAM, UQIC).

### Description

#### Female

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 5.0; length 5.1; eye length 3.8; lower interocular distance 2.8; upper interocular distance 3.2; interantennal distance 0.6; antennocular distance 0.8; interocellar distance 1.1; ocellocular distance 0.8; labrum length 0.4, about 2.5 x as wide as long.

Clypeus with anterior margin truncate, well below lower level of eyes, seen in profile convex; facial foveae about one third length of eyes, curving slightly towards lateral ocelli; genal area less than half as wide as eye seen from side (almost invisible below anterior third of eye); gastral foveae about 3 x as long as wide. Head including maxillary and labial palps and mesosoma black; metasoma reddish brown; fore and mid legs dark brown, hind legs basally dark brown, tibiae and tarsi brown; forewing with pterostigma yellow, veins and margins of pterostigma dark brown, clypeus and supraclypeal area least heavily punctured; pubescence long, white, on vertex and genae, mesosoma (including legs), venter; long brownish setae on  $T_5$ ,  $T_6$ .

### Remarks

The distinctly yellow opaque pterostigma differs from the usual transparent, yellowish-brown with dark brown margins.

### Etymology

The specific name refers to the species of *Verticordia* on which the specimens were found.

### *Dasyhesma robusta* Michener

*Dasyhesma robusta* Michener, 1965: 284–285

### Types

**Western Australia:** holotype ♀, Pearce, 6 January 1956, A.M. Douglas (WAM). Paratypes: **Western Australia:** 2♀, same data as holotype (WAM); 1♀, same data on 1 January 1956 (WAM); allotype ♂, Capel, 2 January 1941, P.N.F. (WAM); 4♀, same data as allotype (KU).

### Description

See Michener, 1965 pp. 284–285.

The following measurements are for comparison with other species described.

#### Female

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 6.0; length 5.1; eye length 4.0; lower interocular distance 2.9; upper interocular distance 4.1; interantennal distance 0.9; antennocular distance 0.8; interocellar distance 1.2; ocellocular distance 1.0.

#### Male

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 5.0; length 4.4; eye length 3.1; lower interocular distance 2.1; upper interocular distance 3.5; interantennal distance 0.8; antennocular distance 0.7; interocellar distance 1.1; ocellocular distance 0.9.

### Remarks

The specimen from Bullsbrook numbered 46-2576 in WAM although labelled by Michener "Paratype *Dasyhesma robusta*" is here identified as *D. scholtzia*.

### *Dasyhesma simulata* sp. nov.

Figures 18, 22, 30

### Types

**Western Australia:** holotype ♀, 13km 35°S of W from Eurardy HS, 27°37'52"S, 114°34'01"E, 6–9 November 1999, T.F. Houston, on flowers of *Verticordia dichroma* var. *dichroma* (WAM). Paratypes: **Western Australia:** 1♀, same data as holotype; 1♂, 11.5km 24°S of W from Eurardy HS,

27°36'30"S, 114°33'59"E; 1♂, 10.5km W of Eurardy HS, 27°33'45"S, 114°33'59"E, both males, 6 November 1999, T.F. Houston, on flowers of *Verticordia dichroma* var. *dichroma* (WAM).

### Additional Material Examined

**Western Australia:** 7♂, 10km WNW of Eurardy HS, 21–24 October 1998, T.F. Houston and O. Mueller, on flowers of *Verticordia dichroma* var. *dichroma* (WAM).

### Description

#### Female

Length about 8.0mm; wing length about 5.0mm. Relative head measurements: width 5.1; length 5.2; eye length 4.0; lower interocular distance 2.7; upper interocular distance 3.4; interantennal distance 0.7; antennocular distance 0.8; interocellar distance 1.0; ocellocular distance 0.8; labrum length 0.5, about 2 x as wide as long.

Basitibial plate margined by posterior carina terminating in one tubercle; inner hind tibial spur with 5 teeth.

Colour as in *galbina* with less yellow – labial palp segments 3 and 4 pale, antennal flagellar segments 4–10 yellow ventrally, fore legs predominantly dark brown not yellow-orange.

#### Male

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 4.7; length 4.6; eye length 3.5; lower interocular distance 2.3; upper interocular distance 3.2; interantennal distance 0.4; antennocular distance 0.5; interocellar distance 0.9; ocellocular distance 0.8; labrum length 0.3, about 2.7 x as wide as long.

Very similar to *galbina* except in size and with labrum more sharply triangular, less yellow colouring and T<sub>7</sub> dark brown.

Genitalia: Figure 18.

Seventh metasomal sternum: Figure 30.

### Remarks

Both sexes resemble *D. galbina* differing in size and colouring. In both species segment 2 of the labial palps is large, about 0.75 x length of segment 3.

Both *D. galbina* and *D. simulata* were associated with *Verticordia dichroma* on the different varieties *syntoma* and *dichroma*.

Code number in Houston (2000): M364

### Etymology

The specific name is from 'similis', the Latin word for like, and refers to the similarity to *D. galbina*.

### *Dasyhesma spicata* sp. nov.

## Type

**Western Australia:** holotype ♀, 54km, 27°E of N from Kalbarri on VP Fence, 27°16'02"S, 114°25'15"E, 24 November 1998, T.F. Houston, on flowers of *Verticordia spicata* (WAM).

Two females were collected at this site on this date, one on flowers of *V. spicata*, the other on flowers of *V. spicata* × *dichroma*. They differ particularly in shape of head and colouration.

In his revision of *Verticordia*, George (1991) cited hybrids. It is interesting that the bee on the hybrid is *D. syntoma* without the usual dark colour to the last tarsal segments of legs 2 and 3.

## Description

### Female

Length about 7.0mm; wing length about 4.5mm. Relative head measurements: width 5.0; length 4.9; eye length 3.6; lower interocular distance 2.4; upper interocular distance 3.0; interantennal distance 0.7; antennocular distance 0.7; interocellar distance 1.0; ocellocular distance 0.6; labrum length 0.4, about 2.5 × as wide as long.

Facial foveae reaching level of ocelli; gastral foveae not seen; basitibial plate with anterior and posterior carinae each terminating in a tubercle; forewing with veins and margins of pterostigma dark brown; head and mesosoma black, metasoma orange brown; fore and mid legs with coxae, trochanters and femora black; hind legs and tibiae and tarsi of mid legs orange/yellow; fore tibiae brown marked with yellow; fore tarsi brown.

Punctures surrounding ocelli and mesonotum almost touching, on clypeus sparse; propodeum polished.

Longish white setae on ventral body surface; short, white setae on dorsum of head and mesonotum.

## Etymology

The specific name is taken from the species of *Verticordia* on which it was found.

*Dasyhesma syntoma* sp. nov.

Figure 3

## Types

**Western Australia:** holotype ♀, 51km 17° E of N from Kalbarri on VP Fence, 27°15'19"S, 114°19'58"E, 16–19 November 1998, T.F. Houston, on flowers of *Verticordia dichroma* var. *syntoma* (Myrtaceae) (WAM). Paratypes: **Western Australia:** 4♀, 1♂, same data as holotype (WAM, UQIC).

## Additional Material Examined

**Western Australia:** 1♀, 9km S of Nerren Nerren HS on NW Coastal Highway, 25 October 1996, T.F.

Houston, on *Verticordia dichroma* var. *syntoma* (WAM).

## Description

### Female

Length about 7.0mm; wing length about 5.0mm. Relative head measurements: width 4.8; length 5.0; eye length 4.0; lower interocular distance 2.5; upper interocular distance 3.2; interantennal distance 0.7; antennocular distance 0.7; interocellar distance 1.0; ocellocular distance 0.7; labrum length 0.4, about 2.5 × as wide as long.

Labial palps with segment 3 about 2.5 × length of segment 2; genal area narrower than eye seen from the side; basitibial plate margined by carinae with two tubercles at end of posterior carina; inner hind tibial spur with 5–7 teeth; foveae of second tergum of metasoma about 6 × as long as wide.

Head black with labial palps dark brown; labrum and underside of last seven segments of antennal flagellum yellow-brown; mesosoma black with coxae, trochanters and femora of fore legs black, tibiae and tarsi of fore legs and all mid and hind legs orange; metasoma orange. Long white hair on underside of body, shorter on dorsum, clypeus sparsely punctured.

### Male

The only male collected with females is in pieces and the length cannot be measured.

Wing length about 5.0mm. Relative head measurements: width 4.8; length 4.5; eye length 3.5; lower interocular distance 2.2; upper interocular distance 3.1; interantennal distance 0.4; antennocular distance 0.6; interocellar distance 1.0; ocellocular distance 0.9. Anterior margin of clypeus slightly concave; labrum length 0.3, about 3 × as wide as long.

## Remarks

*D. syntoma* was collected on the same variety of *Verticordia dichroma* as *D. galbina*. Most obvious distinctions in females relate to length and colour of segments of labial palps and colour of legs.

Code number in Houston (2000): F399.

## Etymology

The specific name refers to the variety of *Verticordia dichroma* on which specimens were collected.

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## Fish fauna of the Fitzroy River in the Kimberley region of Western Australia – including the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri Aboriginal names

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**Abstract** – This project surveyed the fish fauna of the Fitzroy River, one of Australia's largest river systems that remains unregulated, located in the Kimberley region of Western Australia. A total of 37 fish species were recorded in the 70 sites sampled. Twenty-three of these species are freshwater fishes (i.e. they complete their life-cycle in freshwater), the remainder being of estuarine or marine origin that may spend part of their life-cycle in freshwater. The number of freshwater species in the Fitzroy River is high by Australian standards. Three of the freshwater fish species recorded are currently undescribed, and two have no formal common or scientific names, but do have Aboriginal names. Where possible, the English (common), scientific and Aboriginal names for the different species of the river are given. This includes the Aboriginal names of the fish for the following five languages (Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri) of the Fitzroy River Valley. The fish fauna of the river was shown to be significantly different between each of the lower, middle and upper reaches of the main channel. Furthermore, the smaller tributaries and the upper gorge country sites were significantly different to those in the main channel, while the major billabongs of the river had fish assemblages significantly different to all sites with the exception of the middle reaches of the river. The previously known ranges of many species were extended. The implications of damming the Fitzroy River are discussed.

### INTRODUCTION

The Kimberley region of Western Australia is home to a unique assemblage of freshwater fishes that is exposed to high summer rainfall and a dry winter period. Much of the landscape is rugged, with vehicular access seasonally limited. This, together with the isolation of the region, has resulted in only limited distributional fish faunal surveys being conducted. Fish surveys have often revealed species that are new to science, or have greatly extended the ranges of the species captured. The most notable surveys of the Kimberley include those on the Gibb River Road to the Drysdale River (by Rosen, Nelson and Butler in 1969 for the American Museum of Natural History), the Ord River area (McKay, 1971), the Prince Regent River (Allen, 1975), Drysdale River (Hutchins, 1977), Mitchell, King Edward and Lawley rivers (Hutchins, 1981), Hutchins and Chapman (Hutchins, unpublished data) surveyed the Gibb River Road in 1975 (see Hutchins, 1981), Allen and Allen sampled stream crossings on the Gibb River and Kulumburu roads (Allen and Allen,

unpublished data) and Allen and Leggett (1990) sampled numerous sites on the Isdell, Mitchell, King Edward, Drysdale and Ord rivers. Surprisingly, the largest river of the Kimberley, the Fitzroy, which drains over one-third of the region, has only been surveyed in a few easily accessed locations (see Allen and Leggett, 1990).

The Fitzroy River is large by Western Australian standards, draining almost 90 000 km<sup>2</sup>, and is largely uncleared, with its water non-saline throughout most of its length (Anon, 1993; Storey, 1998). The Fitzroy River is one of the largest unregulated rivers in Australia, but has recently been identified as having the potential to supply quality water to not only the Kimberley, but also other parts of Australia (Anon, 1993; Storey, 1998). A number of dam sites have been recognised including Dimond Gorge and Margaret Gorge (Anon, 1993). While providing water for agriculture and domestic uses, the proposed dams have been seen by some as a means of controlling natural flooding in the Fitzroy River floodplain (Anon, 1993).

The Fitzroy River catchment experiences a semi-

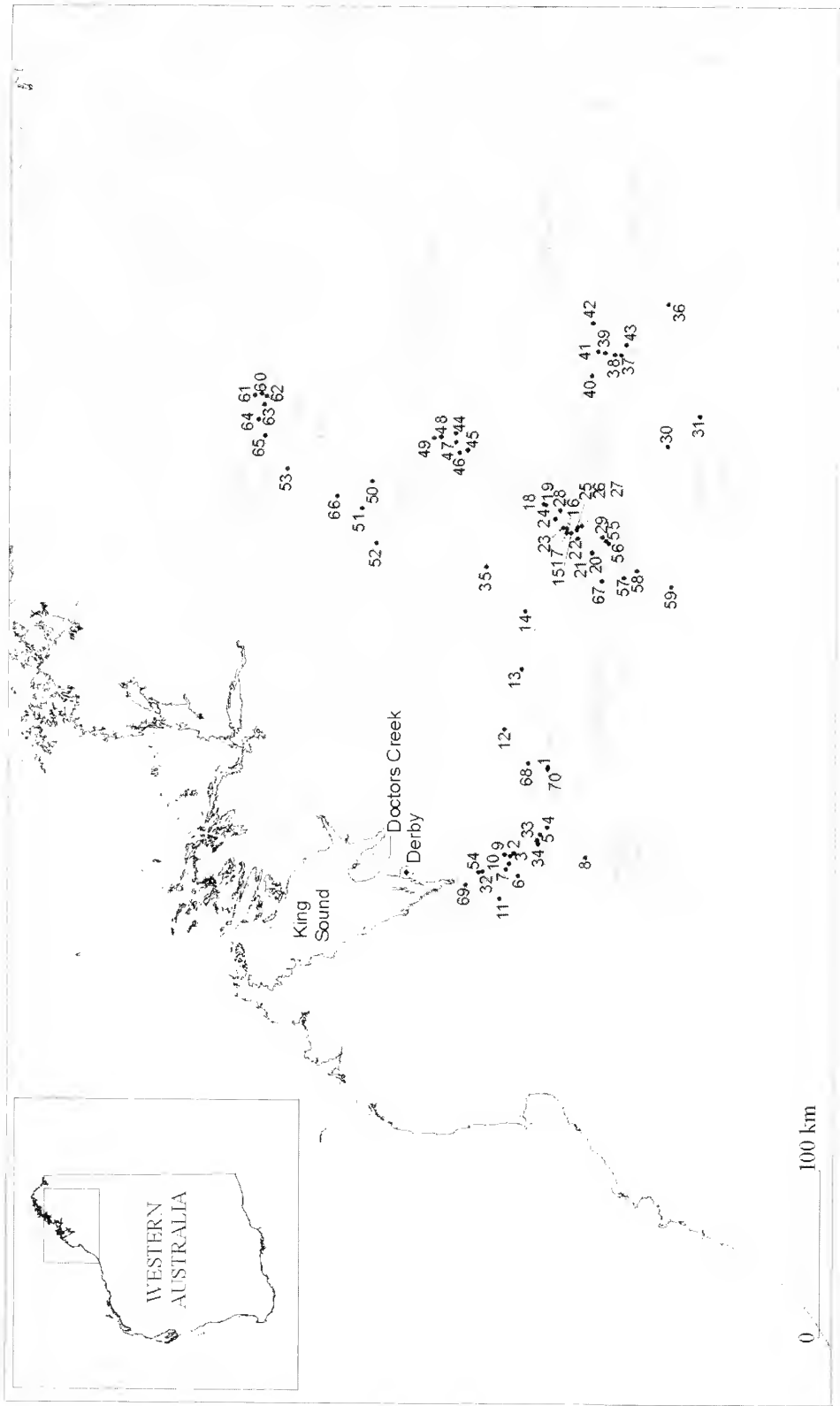


Figure 1 The sites sampled for fish in the Fitzroy River, Western Australia.

arid to arid monsoonal climate receiving most (~90%) of its rainfall between November and March (i.e. the wet season) (Goh, 1998; Ruprecht and Rodgers, 1998). Upstream of Fitzroy Crossing the river catchment covers approximately 45 000 km<sup>2</sup> and divides into two main tributaries, the Fitzroy and Margaret rivers, which also encompass the high relief reaches of the river (Ruprecht and Rodgers, 1998). The main tributaries of the upper Fitzroy include the Hann, Adcock, Louisa and Little Fitzroy rivers, while those of the Margaret include the Mary, Leopold, O'Donnell, Gidden, Little Gold and Laura rivers (see Figure 1) (Ruprecht and Rodgers, 1998). Downstream of Fitzroy Crossing lies the river floodplain, which extends some 300 km to the coast, and includes the tributaries of Christmas, Mt Hardman, Mt Wynne and Geegully creeks. The mean annual streamflow of 6 150 GL/year (since the 1950s) at Fitzroy Crossing is the highest of any river system recorded in Western Australia (Ruprecht and Rodgers, 1998). While flows peak during the wet season, in the dry season flow may cease with the river becoming a series of disconnected pools and billabongs. Turbidity is also seasonally affected, with highest turbidities coinciding with peak flows during the wet season (Ruprecht and Rodgers, 1998).

The present study represents part of an ongoing collaboration between Murdoch University, the Kimberley Land Council, the Kimberley Language Resource Centre and the local community, including the traditional owners and station owners, of the Fitzroy River catchment. The importance of the Fitzroy River to the Aboriginal people of the region is highlighted in this report, and where possible, the Bunuba, Gooniyandi, Ngarinyin, Nyikina, Walmajarri, English (common) and scientific names are given for each fish species recorded from the Fitzroy River system. A further aim of this project was to address the notable lack of distributional data for the fish fauna of the Fitzroy River, while also examining the fish faunal associations within the various habitat types of the river. Furthermore, the importance of the river to the people of the Kimberley region and the conservation issues affecting fish distributions are discussed.

## MATERIALS AND METHODS

### Sampling for fish

During four two-week surveys, between April 2001 and November 2002, and two short field trips in March and December 2002, a total of 70 sites were sampled for fish throughout the main channel of the Fitzroy River, its tributaries and associated wetlands/billabongs (see Appendix 1). Many of the sites are of Aboriginal significance and located

within areas covered by native title applications, and the survey team was guided by traditional owners and their knowledge. With the exception of one site (Telegraph Pool), all sites sampled in the river were above the limit of tidal influence. Additionally, species recorded in the estuary and Doctor's Creek, near the mouth of the Fitzroy River (see Figure 1), during opportunistic sampling, are included in the results.

Sampling equipment included a variety of seine nets [1 m (1 mm mesh), 5, 10 and 15 m (all 3 mm mesh), 26 m (6 and 3 mm mesh) and a 60 m (10 and 5 mm mesh)], gill nets (25 to 125 mm stretched mesh sizes), cast nets, masks and snorkels and hooks and lines.

Active participants included the Centre for Fish and Fisheries Research at Murdoch University, the Land + Sea Management Unit at the Kimberley Land Council (KLC), the Fitzroy Crossing Kimberley Language Resource Centre (KLRC), station owners and tenants, and community members from Broome, Derby and Fitzroy Crossing and their surrounds, including the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri traditional owners.

### Environmental variables

The conductivity, temperature and pH of water taken just below the surface were recorded at each sample site.

### Species identification and maps

Each species captured was photographed with some specimens preserved for identification and for the collections of the Western Australian Museum. The majority of fish were released alive after capture. The phylogenetic order of the families (and the subsequent species list) follows Nelson (1994). Longitude and latitude were recorded at each site using a Global Positioning System (GPS). The sample sites map was created using the above GPS data and MapInfo (MapInfo Corporation, 1998).

### Classification of sample sites and Analysis of Similarity (ANOSIM)

In order to test the hypothesis that fish faunal composition would vary between the lower (sites 1–6, 9, 32–34, 54, 68, 70), middle (15–16, 18–20, 28, 57, 67) and upper (36–41, 44–45) reaches of the main channel/major tributaries of the river and also the smaller tributaries (sites 8, 11–14, 17, 22–25, 27, 30–31, 35, 43, 46–52, 55–56, 58–59), the large lentic billabongs (sites 7, 10, 21, 26, 29) and the upper gorge country e.g. upper Hann River (sites 42, 53, 60–66) (see Figure 1), the sample sites were *a priori* allocated to one of these broad habitat categories and their fish community structures compared using one-way analysis of similarity (ANOSIM) in PRIMER (Clarke and Gorley, 2001).

In order to test for differences in community structure, a presence-absence data set of the different species captured in the 70 sites sampled in the Fitzroy River catchment was used to construct a similarity matrix employing the Bray-Curtis similarity coefficient in the PRIMER package (Clarke and Gorley, 2001). The presence-absence data were considered to be more appropriate than abundance data for a number of reasons: 1. Water

levels, and thus sampling efficiency, varied greatly between the sampling periods, i.e. late wet and late dry; 2. The level of sampling effort was governed by site characteristics, e.g. size and depth; 3. The requirement of a number of capture techniques to effectively sample the variety of species in the different sites, e.g. different meshed seine nets (larger net generally equals larger mesh size), mask and snorkel only in clear waters, seine nets not as

**Table 1** The sites at which the different freshwater fish species were captured in the Fitzroy River (see Figure 1 for site localities and Table 3 for common and Aboriginal names).

Freshwater species	Site numbers	Total
Anguillidae		
<i>Anguilla bicolor</i> McClelland, 1844	18	1
Clupeidae		
<i>Nematalosa erebi</i> (Günther, 1868)	1–9, 11–12, 15–20, 23, 25–27, 29–34, 36–45, 49–50, 54, 57–59, 61–62, 65–68	49
Ariidae		
<i>Arius graeffei</i> Kner and Steindachner, 1867	1, 3–4, 18–19, 26, 29, 32, 34, 36, 38–41, 44–45, 57, 67–70	21
Plotosidae		
<i>Anodontiglanis dahli</i> Rendahl, 1922	1–2, 4, 10, 12, 25, 34, 68	8
<i>Neosilurus ater</i> (Perugia, 1894)	45	1
<i>Neosilurus hyrtlii</i> Steindachner, 1867	1–7, 9–10, 12–19, 24, 29–34, 36, 38, 42–43, 45, 47, 54, 63–64	33
<i>Neosilurus pseudospinosus</i> Allen and Feinberg, 1998	36, 38, 42, 45, 53	5
<i>Porochilus rendahli</i> (Whitley, 1928)	10, 12, 15, 21, 24, 26, 29, 56	8
Belonidae		
<i>Strongylura krefftii</i> (Günther, 1866)	1, 3–4, 6, 9, 15–18, 20, 23, 26, 29, 32–34, 37, 39–41, 44–45, 67–68	24
Melanotaeniidae		
<i>Melanotaenia australis</i> (Castelnau, 1875)	2, 4–9, 12–15, 17–31, 33, 35–43, 45–54, 58–66, 68	56
Atherinidae		
<i>Craterocephalus lentiginosus</i> Ivantsoff, Crowley and Allen, 1987	7, 10, 15–18, 20–21, 29, 55, 67–68	12
Ambassidae		
<i>Ambassis</i> sp. 1	16, 18–24, 26–29, 43, 45–51, 53–56, 61, 64–66	28
<i>Ambassis</i> sp. 2	2–6, 9–13, 15–17, 20, 23, 33, 35, 45, 54, 58, 67–68	22
Apogonidae		
<i>Glossantia aprion</i> (Richardson, 1842)	1–2, 7, 10, 15–20, 26, 28–29, 33, 56, 58, 67–69	19
Toxotidae		
<i>Toxotes</i> sp.	1–7, 10, 12, 15–18, 26, 28–29, 32–34, 40, 42–46, 49, 54, 57, 67–68	30
Teraponidae		
<i>Amniataba percoides</i> (Günther, 1864)	9, 16–20, 26, 28–29, 36, 38–46, 48–49, 53, 55, 60–61, 65, 67–68	28
<i>Hannia greenwayi</i> Vari, 1978	36–37, 40, 42, 45–46, 61, 66–67	9
<i>Hephaestus jenkinsi</i> (Whitley, 1945)	3, 16, 18, 25–26, 28, 31–32, 34, 38, 40, 42, 44–46, 48–49, 53, 57, 61, 65–68	24
<i>Leiopotherapon unicolor</i> (Günther, 1859)	1–26, 28–43, 45–54, 56–68	65
Eleotridae		
<i>Hypseleotris kimberleyensis</i> Hoese and Allen, 1983	53, 65	2
<i>Mogurnda oligolepis</i> Allen and Jenkins, 1999	53, 61, 66	3
<i>Oxyeleotris sellheimi</i> (Macleay, 1884)	10, 17, 22, 29, 33, 36, 40, 43, 48–49, 55	11
Gobiidae		
<i>Glossogobius giuris</i> (Hamilton, 1822)	2–5, 7–8, 16, 18–20, 23, 26–29, 32–33, 36–46, 48, 54–55, 57–59, 66–68	38



effective as gill nets or hook and line for capturing larger species (e.g. barramundi, lesser salmon catfish and freshwater sawfish). Thus, estimates of relative abundance could not be standardised for all sites.

Aboriginal names for the fish

During and after field trips, linguists from the KLRC and KLC consulted Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri language speakers from communities of the Fitzroy River valley. Where possible, traditional owners were consulted in the field using live fishes, however it was also necessary to show photographs of species that were not captured on specific field trips. Fish names were recorded, wherever possible, for each of the species captured.

RESULTS

Environmental variables

The mean pH of the sites sampled (Appendix 1, Figure 1) was 8.17 ( $\pm 0.085$  s.e.) and ranged from 6.8 to 10.6. With the exception of one site, all sites sampled were alkaline. The water temperatures of the sites sampled ranged from 15.1 to 33.0 °C and had a mean of 26.8 °C ( $\pm 0.68$  s.e.). The coldest site

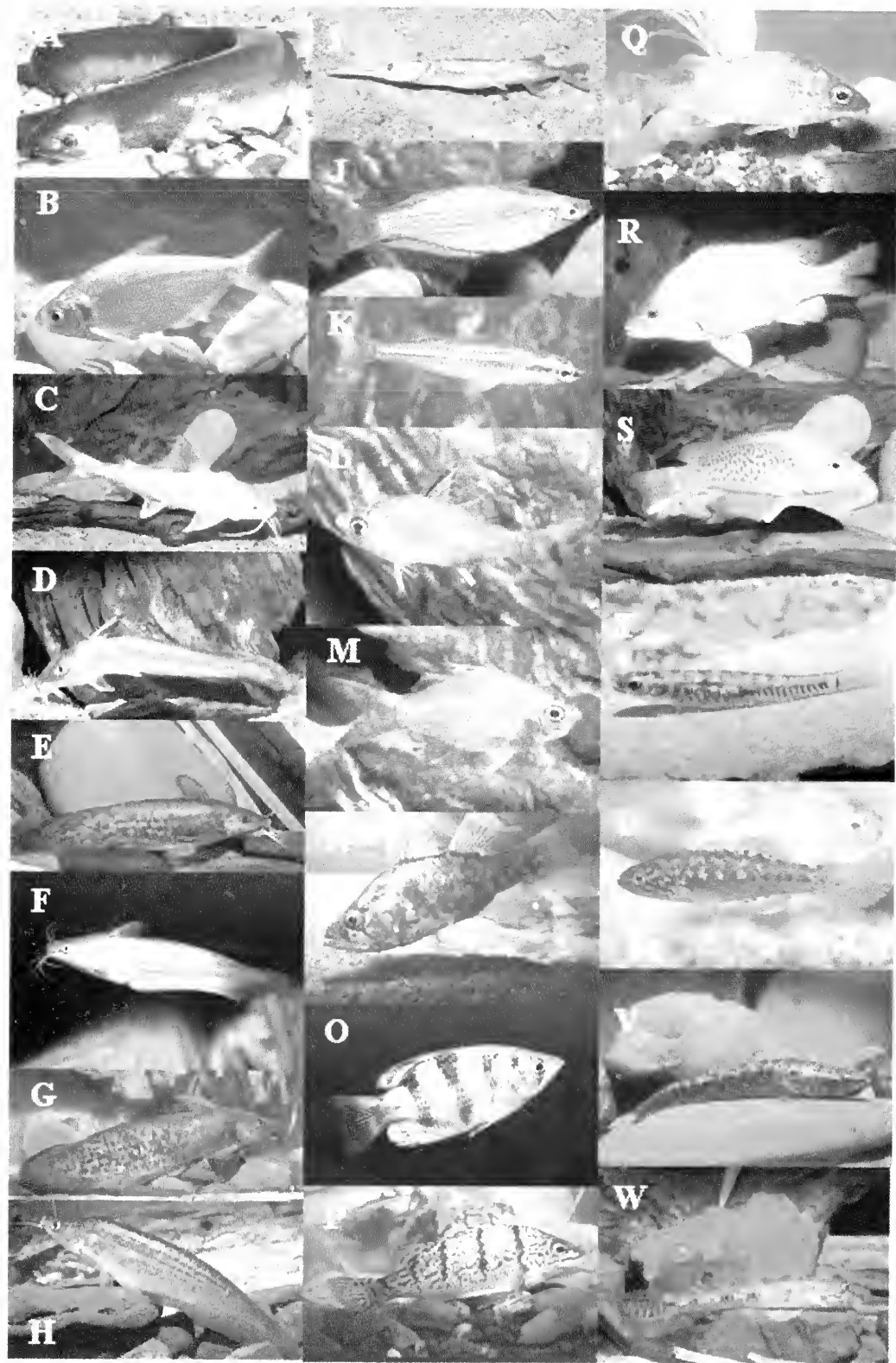
(site 64), which was sampled in June, was in the Hann River. With the exception of the estuarine site (Telegraph Pool, site 69), which was 6 ppt ( $\sim 9$  mScm<sup>-1</sup>), and Mangel Creek (site 11), which had a salinity of 19.4 ppt, all sites sampled were freshwater. The mean conductivity of all other sites was 0.89 mScm<sup>-1</sup> ( $\pm 0.383$  s.e.).

Fish species captured

The 70 sample sites (Appendix 1, Figure 1) in the Fitzroy River yielded a total of 37 species in 31 genera from 23 families (Plates 1 and 2, Tables 1 and 2). Of these, 23 species are primarily freshwater fishes, while 14 species are considered of estuarine or marine origin but may spend part of their life-cycle in the freshwaters. For the purposes of this paper, a freshwater species is defined as one that is either restricted to freshwater, breeds in freshwater or spends the majority of their life-cycle in freshwater. Marine and estuarine species are defined as those that sometimes penetrate freshwaters, but predominantly occur and/or breed in marine or estuarine environs. An exception should be noted, that being the short-finned eel (*Anguilla bicolor*), which breeds in the sea, but was included in the freshwater category as it spends the majority of its life in freshwaters. The lesser salmon catfish (*Arius graeffei*), which is found in both fresh

**Table 2** The sites at which the different marine/estuarine fish species were captured in the freshwaters of the Fitzroy River (see Figure 1 for site localities and Table 4 for common and Aboriginal names).

Marine/estuarine species	Site numbers captured at	Total
Carcharhinidae		
<i>Carcharhinus leucas</i> (Valenciennes, 1839)	57, 69, 70	3
Pristidae		
<i>Pristis microdon</i> Latham, 1794	3–4, 20, 34, 40–41, 57, 68–70	9
<i>Pristis clavata</i> Garman, 1906	69	1
Dasyatidae		
<i>Himantura chaophraya</i> Monkolpraist and Roberts, 1990	57, 69, 70	3
Elopidae		
<i>Megalops cyprinoides</i> (Broussonet, 1782)	2, 18–19, 40, 68	5
Mugilidae		
<i>Liza subviridis</i> (Valenciennes, 1836)	1–4, 9, 32, 34, 40, 69	9
<i>Liza alata</i> (Steindachner, 1892)	33, 68	2
Centropomidae		
<i>Lates calcarifer</i> (Bloch, 1790)	2–4, 9, 18, 26, 28–29, 32, 34, 36, 40–41, 43, 45, 57, 67–70	20
Gerreidae		
<i>Gerres filamentosus</i> Cuvier, 1829	32	1
<i>Gerres subfasciatus</i> Cuvier, 1830	9	1
Sciaenidae		
<i>Nibea squamosa</i> Sasaki, 1992	34	1
Scatophagidae		
<i>Scatophagus argus</i> (Linnaeus, 1766)	7	1
<i>Selenotoca multifasciata</i> (Richardson, 1846)	3–4, 32	3
Tetraodontidae		
<i>Marilyna meraukensis</i> (de Beaufort, 1955)	32, 34, 69	3



and salt waters, has also been included in the freshwater category because it breeds in freshwater.

Of the 23 species of principally freshwater fishes (Table 1, Plate 1) recorded during the survey, the families Plotosidae (eel-tailed catfishes), Terapontidae (grunters) and Eleotridae (gudgeons) were best represented with five, four and three species recorded, respectively. A number of 'ecological generalist' species were found to be widespread throughout the various broad habitat types. These included the spangled perch (*Leiopotherapon unicolor*) (recorded at 65 of 70 sites), western rainbowfish (*Melanotaenia australis*) (56 of 70 sites) and bony bream (*Nematalosa erebi*) (49 of 70 sites). Other species, including the black catfish (*Neosilurus ater*) (recorded at one site), Barnett River gudgeon (*Hypseleotris kimberleyensis*) (two sites), false-spotted gudgeon (*Mogurnda oligolepis*) (three sites), Greenway's grunter (*Hannia greenwayi*) (nine sites) and false-spined catfish (*Neosilurus pseudospinosus*) (five sites) were rare with restricted distributions in the upper reaches and headwaters of the Fitzroy River catchment. A number of species were found in moderate numbers but only in the lower and middle reaches of the main river channel, including toothless catfish (*Anodontiglanis dahli*), Rendahl's catfish (*Porochilus rendahli*) and Prince Regent hardyhead (*Craterocephalus lentiginosus*). The short-finned eel (*Anguilla bicolor*) was only recorded at one site, but this species is secretive and difficult to capture, therefore it may be more common and widespread than indicated by the results of this survey. Two glassfishes (Ambassidae) (*Ambassis* sp. 1 and *Ambassis* sp. 2) do not conform to any keys and show sufficient morphological differences to the described species to warrant species recognition. These species are currently being described by the senior author. Furthermore, one undescribed species of archerfish (Toxotidae, *Toxotes* sp.) was captured throughout the river and is currently being described by Dr G. Allen.

Of the 14 fish species considered to be estuarine/marine opportunists captured in the freshwaters of the Fitzroy River (Table 2, Plate 2), most were found in small numbers only in the lower reaches of the main river channel (e.g. dwarf sawfish (*Pristis clavata*), mullets (*Liza* spp.), whipfin silverbiddy (*Gerres filamentosus*), roach (*Gerres subfasciatus*), scaly croaker (*Nibea squamosa*), spotted scat (*Scatophagus argus*), striped butterflyfish (*Selenotoca multifasciata*)

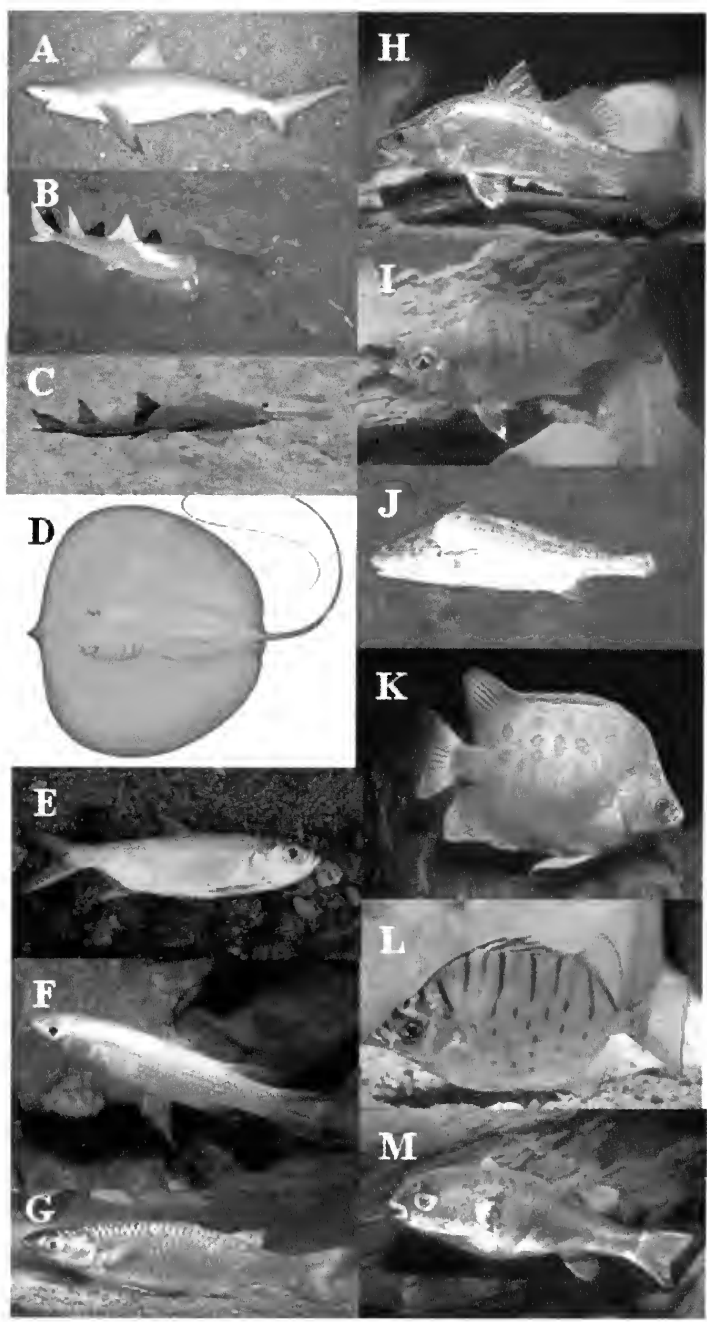
and Merauke toadfish (*Marilyna meraukensis*)). However, barramundi (*Lates calcarifer*) were collected in moderate numbers throughout the main river channel and major tributaries up to ~ 400 km inland. Other species that were captured well upstream of the estuary, albeit in small numbers, were the bull shark (*Carcharhinus leucas*), freshwater sawfish (*Pristis microdon*), freshwater whiplay (*Himantura chaophraya*), tarpon (*Megalops cyprinoides*) and greenback mullet (*Liza subviridis*).

Other species that were captured in the greater estuary of the Fitzroy River (i.e. King Sound), including Doctors Creek (Figure 1) are: the northern river shark (*Glyphis* sp. C), the milk shark (*Rhizoprionodon acutus* (Rüppell, 1837)), the winghead shark (*Eusphyra blochii* (Cuvier, 1816)), the dwarf sawfish (*Pristis clavata*), the lesser salmon catfish (*Arius graeffei*), shark mullet (*Rhinomugil nasutus* (De Vis, 1883)), king threadfin (*Polydactylus macroclit* (Günther, 1867)), scaly croaker (*Nibea squamosa*) and milk-spotted toadfish (*Chelonodon patoca* (Hamilton, 1822)). The northern river shark (*Glyphis* sp. C), which was captured in Doctors Creek, is extremely rare, and has not previously been recorded from Western Australia. It was previously known only from a few specimens collected in the Adelaide, East Alligator and South Alligator rivers in the Northern Territory and from the Fly River in Papua New Guinea (Taniuchi *et al.*, 1991; Compagno and Niem, 1998; Thorburn *et al.*, 2003; Museum and Art Galleries of the Northern Territory records).

### Spatial distribution of fish species in the Fitzroy River

Localised fish communities in the Fitzroy River were shown to vary significantly ( $p < 0.001$ ) between the upper, lower and middle reaches of the main channel/major tributaries (Table 3, Figure 1). These differences can largely be attributed to the higher occurrence of marine species in the lower and, to a lesser extent, middle reaches of the river, as well as to the disparity in species diversity between the lower (27 species), middle (22 species) and upper (17 species) reaches. Furthermore, ANOSIM suggested that the fish fauna associated with the smaller tributary sites and the upper Hann River gorge sites is significantly different to those in each of the lower, middle and upper riverine sites as well as the larger billabongs ( $p < 0.008$ ). The gorge and

◀ **Plate 1** The freshwater fish species of the Fitzroy River, Western Australia. A. *Anguilla bicolor*. B. *Nematalosa erebi*. C. *Arius graeffei*. D. *Anodontiglanis dahli*. E. *Neosilurus ater*. F. *Neosilurus hyrtlii*. G. *Neosilurus pseudospinosus*. H. *Porochilus rendahli*. I. *Strongylura krefftii*. J. *Melanotaenia australis*. K. *Craterocephalus lentiginosus*. L. *Ambassis* sp.1. M. *Ambassis* sp.2. N. *Glossamia aprion*. O. *Toxotes* sp. P. *Amniataba percoideus*. Q. *Hannia greenwayi*. R. *Hephaestus jenkinsi*. S. *Leiopotherapon unicolor*. T. *Hypseleotris kimberleyensis*. U. *Mogurnda oligolepis*. V. *Oxyeleotris selheimi*. W. *Glossogobius giuris*. Photographs: D. Morgan (A, F, I, N-Q, U) and M. Allen (B-E, G-H, J-M, R-S, V-W).



**Plate 2** The marine/estuarine fish species found in the freshwaters of the Fitzroy River, Western Australia. A. *Carcharias leucas*. B. *Pristis microdon*. C. *Pristis clavata*. D. *Himantura chaophraya*. E. *Megalops cyprinoides*. F. *Liza subviridis*. G. *Liza alata*. H. *Lates calcarifer*. I. *Gerres filamentosus*. J. *Nibea squamosa*. K. *Scatophagus argus*. L. *Selenotoca multifasciata*. M. *Marilyna meraukensis*. Not shown is *Gerres subfasciatus*. Photographs: D. Morgan (A-B, E, G, J), M. Allen (F, H-I, K-M), D. Thorburn (C) and J. Ruse (D).

**Table 3** R-stat values for pairwise ANOSIM comparisons of the fish assemblages captured in the different regions/ habitats of the Fitzroy River. N.B. Significant faunal differences are represented by \* $P<0.01$  and \*\* $P<0.001$ . Global  $R = 0.343$ .

Region	LOWER	MIDDLE	UPPER	TRIBUTARY	BILLABONG
MIDDLE	0.326**	–	–	–	–
UPPER	0.516**	0.323**	–	–	–
TRIBUTARY	0.393**	0.408**	0.355**	–	–
BILLABONG	0.435**	0.016	0.503*	0.284*	–
GORGE	0.781**	0.531**	0.551**	0.011	0.572*

tributary sites are generally dominated by smaller freshwater species, e.g. western rainbowfish (*M. australis*), spangled perch (*L. unicolor*), glassfish (*Ambassis* spp.), barred grunter (*Amniataba percoides*), bony bream (*N. erebi*) (and also the rarer species in the gorges such as the Barnett River gudgeon (*H. kimberleyensis*) and false-spotted gudgeon (*Mogurnda oligolepis*)), but lack the marine species and the lesser salmon catfish (*A. graeffei*). The larger billabongs were significantly different to all other major habitat sites with the exception of those in the middle river.

**Aboriginal names for the fish**

The Aboriginal names (for five languages) for the majority of fishes of the Fitzroy River are presented in Tables 4 and 5. The absence of a few names attests to either the rarity of some of the freshwater species (e.g. Barnett River gudgeon and Greenway’s grunter) and the restriction of some of the marine/ estuarine species to the lower catchment (Nyikina land) (e.g. whipfin silver-biddy, roach, scaly croaker, spotted scat, striped butterfish and Merauke toadfish).

**DISCUSSION**

**Fish fauna of the Fitzroy River**

The importance of fish faunal surveys, particularly in northern Western Australia, is highlighted when considering the results of this study. For example, not only is the reporting of two undescribed species (i.e. *Ambassis* sp. 1 and *Ambassis* sp. 2) a major finding of this study, but the new records and range extensions of nine species in the west Kimberley attests to the necessity for such studies. The following range extensions were made during this project:

- (1) Short-finned eels (*A. bicolor*) were not previously known from the Fitzroy River but have previously been found in the northern Pilbara and western Kimberley (Morgan *et al.*, 2003, Western Australian Museum records).
- (2) Black catfish (*N. ater*) were not previously known from the Fitzroy River catchment,

- their only confirmed habitat in the Fitzroy River is at Dimond Gorge.
- (3) False-spine catfish (*N. pseudospinosus*) in the Fitzroy River was previously only known from Manning Creek (Barnett River) (Allen and Feinberg, 1998) – now extended to include the Mary, Margaret and O’Donnell rivers.
  - (4) Greenway’s grunter (*H. greenwayi*) was known only from the Hann and Isdell rivers, and has only been collected on two previous occasions (Allen and Allen, unpublished data; Rosen, Nelson and Butler in 1969 for the American Museum of Natural History) – now extended to include the Fitzroy, Margaret, Mary, Forest and Adcock rivers.
  - (5) False-spotted gudgeons (*M. oligolepis*) in the Fitzroy River were not previously known from the Adcock River (see Figure 1).
  - (6) *Glyphis* sp. C, which we captured in Doctor’s Creek and is an undescribed speartooth shark that is listed as *Endangered* by Environment Australia, had not previously been recorded in Western Australia and is only known from a few specimens captured in the Adelaide, East Alligator and South Alligator rivers in the Northern Territory and the Fly River in New Guinea (Taniuchi *et al.*, 1991; Compagno and Niem, 1998; Thorburn *et al.*, 2003; Museum and Art Galleries of the Northern Territory records).
  - (7) Dwarf sawfish (*P. clavata*) was not known from the west Kimberley.
  - (8) Scaly croaker (*N. squamosa*) had not previously been recorded in the west Kimberley, although the Western Australian Museum records include a photograph from the northern Kimberley (Hutchins, pers. comm.) and Hutchins (2001) lists the species in the collections of the Western Australian Museum. Allen *et al.* (2002) describes the distribution of this species as being from the Victoria River (NT) east to the Norman River (QLD).
  - (9) Merauke toadfish (*M. meraukensis*) was not previously known to occur west of the Prince Regent River (Allen *et al.*, 2002).

**Table 4** The Aboriginal names for the different freshwater fish species in the Fitzroy River.

Freshwater species	Common name	Bunuba	Gooniyandi	Ngarinyin	Nyikina	Walmajarri
<i>Anguilla bicolor</i>	Indian short-finned eel	Lanyi	-	-	-	-
<i>Nematotusa erebi</i>	bony bream	Laarri	Laarri	Gunangurri	-	Lakarr
<i>Arius graeffii</i>	lesser salmon catfish	Mulurra	Gooloomangarri	Moolirr	Bardjarr oobanyba	Kulamajarti
<i>Anodontiglanis dalili</i>	toothless catfish	Wajuna	Wirlingirri	Ganangad	-	-
<i>Nesilurus ater</i>	black catfish	Manambu	-	-	Wardoo	Jungkali
<i>Nesilurus hyrtlii</i>	Hyrtl's tandan	Joonggali	Joonggali	Walaman	Wirinyboo	Jungkali
<i>Nesilurus pseudospinosus</i>	false-spine catfish	Manambu	-	-	Wardoo	Jungkali
<i>Porochilus rendahli</i>	Rendah's catfish	Jugggali	Joonggali	Walaman	Wirinyboo	Jungkali
<i>Strongylura krefftii</i>	freshwater longtom	Langgaranyi	Langgaranyi	Biyira	Baloon	Langariny
<i>Melanotaenia australis</i>	western rainbowfish	Walmarri	Walmadi	Gooljirimby	Dookool koodany	-
<i>Craterocephalus lentiginosus</i>	Prince Regent hardyhead	Jinbirri	Thinbidi	-	Karlanyjarr	Jinpirr
<i>Anabasis</i> sp. 1	glassfish	Walmarri	Walmadi	Wolaman	Jilbirr	Jinpirr
<i>Anabasis</i> sp. 2	glassfish	Walmarri	Walmadi	Wolaman	Jilbirr	Jinpirr
<i>Glossania aprion</i>	mouth almighty	Thamalji	Thamarli	Danari	Jarbar	Parikamarnu
<i>Toxotes</i> sp.	Kimberley archerfish	Girrwali	Girrwali	Nalawarr	Marrbawool	Marrparl marrpal
<i>Anniatoba percoides</i>	barred grunter	Walarabu	Jarlandi	Birlindirr	Mook mook	Kalirikilirri
<i>Hamia greenwayi</i>	Greenway's grunter	-	-	Emana	-	-
<i>Hephaestus jenkinsi</i>	black bream	Walagga	Jaminbaroo	Emana	Walnga	Jampinyparu
<i>Leiopotherapon unicolor</i>	spangled perch	Bugda	Boomda	Wunggarri	Jarrmoongka	Punta mangu
<i>Hypsocentrus kimberleyensis</i>	Barnett River gudgeon	-	-	-	-	-
<i>Mogurnda oligolepis</i>	false-spotted gudgeon	Luthu	Loothoo	Nyagurlman	-	-
<i>Oxytelotris selheimi</i>	giant gudgeon	Nyaguna	Nyagoorna	Nyagurlman	Loojoo	-
<i>Glossogobius giurus</i>	flathead goby	Nyaguna	-	Ngagulun	Joolany	Luthu

**Table 5** The Aboriginal names for the different marine/estuarine fish species in the Fitzroy River.

Freshwater species	Common name	Bunuba	Gooniyandi	Ngarinyin	Nyikina	Walmajarri
<i>Carcharias lenas</i>	bull shark	Ngan-gu	-	-	Ngawoonkoo	Ngangu
<i>Pristis microdon</i>	freshwater sawfish	Galwany	Galwany	-	Wirridanyiny	Wirridani
<i>Pristis clavata</i>	dwarf sawfish	Galwany	Galwany	-	Wirridanyiny	Wirridani
<i>Himantura chaophraya</i>	freshwater whipray	Baya gawiy	-	-	Biya	Biya
<i>Megalops cyprinoides</i>	Ox-eye herring, tarpon	-	Wayoo	-	Karlanyjarri	-
<i>Liza subviridis</i>	greenback mullet	-	Goolgara	Bulurrngari	Lawoorinyji	-
<i>Liza alata</i>	diamond mullet	-	Goolgara	Bulurrngari	Lawoorinyji	-
<i>Lates calcarifer</i>	barramundi	Balga	Barlga	Deyo	Birloonkoordany	Murrulpal
<i>Gerres filamentosus</i>	whipfin silver-biddy	-	-	-	-	-
<i>Gerres subfasciatus</i>	roach	-	-	-	-	-
<i>Nibea squamosa</i>	scaly croaker	-	-	-	-	-
<i>Scatophagus argus</i>	spotted scat	-	-	-	-	-
<i>Selenotoca multifasciata</i>	striped butterflyfish	-	-	-	-	-
<i>Marilyna meraukensis</i>	Merauke toadfish	-	-	-	-	-

The 37 species of fish captured from the Fitzroy River during this study includes 23 freshwater species and 14 marine species that utilise the freshwaters. In addition to this, Allen and Leggett (1990) reported the strawman (*Craterocephalus stramineus* (Whitley, 1950) = *Quirichthys stramineus*) in the upper reaches of the Mary River (18°42'S, 125°45'E). Allen *et al.* (2002) list the seven-spot archerfish (*Toxotes chatareus* (Hamilton, 1922)) and Allen *et al.* (2002) and Doupé and Lenanton (1998) list the silver cobbler (*Arius midgleyi* Kailola and Pierce, 1988) from the Fitzroy River, however there are no specimens of these species in the WA Museum and it is unlikely that they are found in the Fitzroy River. The WA Museum however, has records of two other marine species from the lower non-tidal freshwaters of the river, i.e. giant herring (*Elops hawaiiensis* Regan, 1909) and the anchovy (*Thyssa aesturia* (Ogilby, 1910)). Thus, the known species that are found in the non-tidal freshwaters of the Fitzroy River can be put at 40 species (24 freshwater and 16 marine/estuarine). This diversity is high by Western Australian standards, with the total number of freshwater species being marginally higher than that recorded for all rivers of the Pilbara (Indian Ocean Drainage Division, 12 species) and south-west (South-west Coast Drainage Division, 10 species) combined (Morgan *et al.*, 1998, 2003; Allen *et al.*, 2002). The Kimberley as a whole is diverse in terms of freshwater fish species, and this survey confirms the Fitzroy River as one of the most species-rich in the region. For example, surveys within the Kimberley by McKay (1971) listed 17 freshwater species from the Ord River, while Allen (1975) identified 18 freshwater species from the Prince Regent River and seven from the Roe River, Hutchins (1977) collected 19 freshwater species from each of Drysdale and Carson rivers (total = 24 sp.) and Hutchins (1981) collected nine freshwater species from the Mitchell River. There is however, likely to be a similar number of freshwater species in the Ord River, with recent surveys by Doupé *et al.* (2003) capturing 19 species in Lake Kununurra and G. Allen and M. Allen (unpublished data) recording one other species in the lake in their total of 12 species. Allen *et al.* (2002) lists a further four freshwater species for the Ord River, taking the known total to 24 species. Within the Northern Territory Pollard (1974) collected 28 freshwater fishes from the East Alligator River and also identified a further 15 predominantly marine species, the majority of which were also captured in the Fitzroy River. Pollard (1974) also included the Aboriginal (Oenpelli) names for many of the species. Bishop *et al.* (2001) listed 37 freshwater fishes from the Alligator Rivers (East and South).

Approximately two-thirds of Australia's 200 freshwater fish species occur within northern Australia and within the Kimberley there are

approximate 50 species of which 18 are endemic (Allen and Leggett, 1990; Allen *et al.*, 2002). The high endemicity of the Kimberley is probably a consequence of the rugged topography and diverse habitats that have acted as isolating mechanisms and have thus enhanced speciation (Allen and Leggett, 1990; Pusey *et al.*, 1995). The high diversity of the Fitzroy River may be both a factor of the large catchment size (e.g. Pusey and Kernard (1996) demonstrated a positive relationship between species richness and catchment area in North Queensland) and the high degree of variable habitats, particularly when comparing the main channel, billabongs and creek systems of the floodplain to the high relief gorge country of the headwaters. The topography of the upper Hann River appears to have had a major influence in governing the evolution of at least a few species, e.g. Barnett River gudgeon (*H. kimberleyensis*) and Greenway's grunter (*H. greenwayi*). Freshwater fishes endemic to the Fitzroy River include: *H. kimberleyensis*, *H. greenwayi* (also found in the Isdell River (Allen and Allen, unpublished data)) and possibly the two undescribed glassfishes (*Ambassis* sp. 1 and sp. 2) and archerfish (*Toxotes* sp.). The absence of a number of species that are endemic to nearby, more northern Kimberley rivers, e.g. five species of Terapontidae (*Hephaestus epirrhinos* Vari and Hutchins, 1978, *Leiopotherapon macrolepis* Vari, 1978, *Syncomistes kimberleyensis* Vari, 1978, *Syncomistes rastellus* Vari and Hutchins, 1978 and *Syncomistes trigonicus* Vari, 1978), four eleotrids (*Hypseleotris ejuncida* Hoese and Allen, 1983, *Hypseleotris regalis* Hoese and Allen, 1983, *Kimberleyeleotris hutchinsi* Hoese and Allen, 1987 and *Kimberleyeleotris notata* Hoese and Allen, 1987), one Atherinidae (*Craterocephalus helenae* Ivantsoff, Crowley and Allen, 1987) and two species of the Melanotaenidae (*Melanotaenia gracilis* Allen, 1978 and *Melanotaenia pygmaea* Allen, 1974), suggests that these species have evolved in these remote, more northern rivers of the Kimberley and that there has been no recent connection between these rivers and the Fitzroy River.

The notable change in fish faunal assemblages throughout the Fitzroy River is highlighted by the fact that there are significant differences in the fish fauna found in the lower, middle and upper main channel and major tributary sites of the Fitzroy River as well as between these sites and the smaller less permanent tributaries on the floodplain and in the upper Hann River. Within the Fitzroy River there is a notable increase in species richness in the lower reaches of the river compared to the headwater streams. For example, 27 species were captured in the lower reaches, 22 in the middle and 17 in the upper reaches of the main channel and major tributaries, while the smaller tributary and upper Hann River sites contained 18 and 13 species,

respectively, and 19 species were captured from the major billabongs of the river.

### Aboriginal values of the Fitzroy River

The Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri people have strong economic, cultural and religious affiliations with the fish, the river and fishing. Fishing is an integral part of life for both Aboriginal and non-Aboriginal people of the Fitzroy River catchment, which is not surprising considering that throughout most of its length large numbers of important food species, e.g. black bream (*H. jenkinsi*), barramundi (*L. calcarifer*) and lesser salmon catfish (*A. graeffei*) are readily captured. The utilisation of live and fresh bait has also led to a good understanding of the smaller species in the river.

Not only are the river, its tributaries, billabongs and large and small pools important for food, but they are extremely valuable from a cultural perspective. For example, many of the sites sampled during this survey, particularly permanent deep pools in gorges and billabongs, are known as 'Living Waters'. They are home to Creator 'snakes' that must be treated with ritual and respect to maintain water flows, renew aquatic life and ensure human welfare. The floodplain environment and riparian zone of the Fitzroy River valley is also important for hunting. Stock on pastoral leases readily accesses the river along most of its length.

The Kimberley Land Council and the Kimberley Language Resource Centre have a wealth of information regarding many aspects of the cultural beliefs and languages of the people of the Fitzroy River. A great deal of language was recorded during these field trips by the KLRC.

### Impacts of a dam on the Fitzroy River

While providing water for agriculture and domestic uses, the proposed dam sites in the Fitzroy River have also been seen as a means of controlling natural flooding in the Fitzroy River, thereby allowing intensive agriculture to be developed as in the case of the lower Ord River (Anon, 1993). A dam would create altered flow regimes and changes in seasonal distributions of flow downstream of the dam and there are uncertainties in relation to the river's hydrology relating to sediment loads, impacts of reduced flows and changes in downstream water quality (Ruprecht and Rodgers, 1998). The reduction in peak flow volumes if either Dimond Gorge or Margaret Gorge were dammed would be about one-third (Anon, 1993). However, while flow would be reduced during the wet, during the dry it would be increased to provide for downstream irrigation (Anon, 1993). The altered flow regimes of the river will inevitably cause a change in the prevailing fish fauna immediately above the dam, but will also

impact the distribution of fish below the dam. Thus migratory species such as barramundi, the endangered freshwater sawfish, ox-eye herring and mullets will no longer have access to habitat above dam sites, but the altered flow regimes and flood levels will also impact the recruitment of other species. The Fitzroy River acts as a nursery for many of these species and in the case of the freshwater sawfish, the river is currently the most important known refuge for the species (see Thorburn *et al.* 2003). Migratory species such as those listed above have been excluded from the Ord River above Lake Kununurra as a result of the diversion dam (Doupé *et al.*, 2003). During the wet season the floodplain environment of the lower Fitzroy is important not only as spawning grounds for many of the river's fishes, but is also likely to act as a nursery ground for many of these species. Any reduction in flooding may therefore inhibit larval recruitment into the adult populations of some species. Furthermore, dams generally favour species that prefer lentic waters over those more conducive to lotic habitats and ultimately alter fish community structure (e.g. Morgan *et al.*, 2002).

One of the proposed dam sites, Dimond Gorge, had the second highest number of species recorded (17) and was the only location where the black catfish (*N. ater*) was collected. Barramundi and the endangered freshwater sawfish are known to migrate at least as far upstream as these sites.

### Grazing

Williams and Pen (1998) noted that much of the upper Fitzroy River catchment shows considerable signs of degradation through heavy grazing, with many large denuded and eroding areas. Much of the riparian zone shows signs of degradation from livestock, while many of the wetlands and billabongs become nutrient enriched and trampled by congregations of cattle during the dry. The trampling of small pools by cattle may impact on benthic species such as the gobies, gudgeons and plotosid catfishes, although further work is required to ascertain any impacts. As a precautionary measure, areas of important fish habitat should be identified and fenced from cattle, e.g. Lake Skeleton (site 10).

### Conclusions

The species richness and uniqueness of the fish fauna of the Fitzroy River, its importance to the people of the west Kimberley for food and recreation, and the diverse significance of the river as a 'living cultural landscape' to Aboriginal people of the region (including the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri) makes it one of Australia's great river systems. The Fitzroy River and its estuary, which provides refuge for a number of rare and little known species (e.g. the endangered



freshwater sawfish, Greenway's grunter, Barnett River gudgeon, false-spotted gudgeon and three undescribed species), warrants careful consideration before any proposed land use changes are implemented.

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## Appendix 1 The sites sampled in the Fitzroy River catchment.

Site Number	Site Locality	Site Number	Site Locality
1	Fitzroy River – Myroodah Crossing	34	Udialla Station – Fitzroy River
2	Minnie River	35	Leopold Station – Little Spring
3	Fitzroy River ~ 5 km downstream of Udialla Station	36	Mary River – Yiyili Community
4	Tributary Fitzroy River ~ 10km upstream Udialla Station	37	Margaret River, Me No Savy
5	Fitzroy River – upstream Udialla Station	38	Margaret River, Joorda Doognhingi
6	Manguel Creek	39	Margaret River, Nyalingi
7	Lake Alma	40	Margaret River, Lambardi
8	Geegully Creek	41	O'Donnell River / Margaret River junction, Balmoongoo
9	Fitzroy River – opposite Minnie River mouth	42	Gorge near Margaret River, Girramoo
10	Lake Skeleton	43	Margaret River
11	Lake on Old Great Northern Hwy	44	Fitzroy River – Cadjeput – Old Mornington Station
12	Lake on Great Northern Hwy ~ 131km wets Fitzroy Crossing	45	Fitzroy River – Dimond Gorge
13	Mt Wynne Creek – Great Northern Hwy	46	Tributary of Dimond Gorge
14	Mt Hardman Creek – Great Northern Hwy	47	Small billabong – tributary of Dimond Gorge
15	Brooking Channel, Baralwani – Great Northern Hwy	48	Anna Creek – Old Mornington Station
16	Old Crossing – Fitzroy River	49	Anna Creek – Old Mornington Station
17	Brooking Creek – Geikie Gorge Rd	50	Adcock River – Old Mornington Station
18	Fitzroy River, Sheep Camp, Wuruiya – Geikie Gorge	51	Tributary of Adcock River
19	Crocodile Creek – Geikie Gorge	52	Grave Creek – Adcock River
20	Wirangarra ~ 20 km south Fitzroy Crossing	53	Manning Creek Gorge
21	Billabong near Wirangarra – small lake near Ngurtawarta community	54	Lower Fitzroy River – Small tributary of Willuns Pool
22	Dawuwarriya – near Ngurtawarta Community	55	Duck Hole Creek – Goray
23	Creek crossing – Geikie Gorge Rd	56	Duck Hole Billabong
24	Gurangajar Creek – Geikie Gorge Rd	57	Fitzroy River – Cherabin Camp
25	Two Mile Creek, Barangari	58	Cherabin Creek – Crocodile Dam (stock dam)
26	Goarii ~ 10km E Fitzroy Crossing off Great Northern Hwy	59	Booline Creek
27	Bluebush Creek ~ 15km E Fitzroy Crossing	60	Hann River, Barlmundurra – Gibb River Rd
28	Margaret River (Mayalnga) – crossing near Muludja Community	61	Hann River Gorge
29	Jiliyardi (billabong near Bayulu community)	62	Hann River – Bella Yards
30	Mimbi Cave (Mt Pierre Station)	63	Snake Creek – Hann River
31	Christmas Creek – Bohemia Downs Station, Kupartiya Community)	64	Snake Creek, Bijili – Hann River
32	Fitzroy River – Willare Bridge	65	Barnett River – downstream of Barnett River Gorge
33	Udialla Station – spring near Oyster Patch	66	Adcock River Gorge
		67	Forest River – Jubilee Downs
		68	Snake Creek – Camballin
		69	Telegraph Pool – Fitzroy River
		70	Camballin – Fitzroy River



## A further record of the spider *Microctenonyx subitaneus* (Araneae: Linyphiidae: Erigoninae) in Australia

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Linyphiids are tiny to medium spiders (1 to 8 mm in body length) that construct sheet webs. Members of the subfamily Erigoninae are smallest (1 to 4 mm). They construct tiny sheet webs under stones, in moss or depressions in the soil (Main 1976; Raven *et al.* 2002a). Despite comprising a large proportion of the European fauna, linyphiids represent only a small proportion of described Australian taxa. The Australian fauna comprises 20 genera and 35 described species (Raven *et al.* 2002b). Five introduced species have been recorded; *Diplocephalus cristatus* (Blackwall), *Eperigone fradeorum* (Berland), *Erigone prominens* Bösenberg and Strand, *Microctenonyx subitaneus* (O.P. Cambridge), and *Ostearius melanopygius* (O.P. Cambridge) (Austin *et al.* 1991; Hirst and Nicolson 1995; Raven *et al.* 2002c).

Here *Microctenonyx subitaneus*, from the Erigoninae, is recorded as an additional genus and species present in Western Australia. This finding supports the previous South Australian record by Hirst and Nicolson (1995). Although *M. subitaneus* is endemic to the holarctic (Platnick 2003), it is known from other regions including Africa and New Zealand (Millidge 1988; Scharff 1990). This widespread occurrence has led to many synonyms being created; seven junior synonyms are known (see Platnick 2003).

Specimen identification was by a match of the male palps to Figures 308 and 310 in Millidge (1988). A dorsal view of the carapace, with prominent sulci (pits) behind the posterior lateral eyes, also matched his Figure 309. Lateral view of the carapace, however, revealed a difference to his Figure 301. Rather than all eyes being located on the anterior surface of the carapace, the posterior median eyes were on the dorsal surface. It is unknown whether this represents an abnormal specimen, some plasticity in eye location, or mechanical damage to the specimen during collection.

Further collecting and/or searches of museum collections might reveal other Australian specimens of *M. subitaneus*. It is likely the specimen detailed here was from an established population rather than an immigrant intercepted at its point of entry.

The latter are found usually in urban areas, particularly shipping ports or areas where goods imported from abroad have been stored (e.g., Harvey 1996). This specimen was collected from a rehabilitated mine pit, surrounded by unmined jarrah (*Eucalyptus marginata*) forest, 45 km south-east of Perth. That said, the species appears difficult to collect at this locality. Of more than 25,000 spiders identified from Jarrahdale Mine, Western Australia, it is the only known specimen.

It is likely that other described linyphiids will be found in Australia. Raven *et al.* (2002c) suggest *Tenuiphantes cristatus* (Menge), may be present although not yet recorded.

### MATERIAL EXAMINED

**Australia: Western Australia:** 1 male, Jarrahdale Mine 32°16'S 116°06'E, vacuum sampled from foliage, 8 year-old rehabilitated mine pit surrounded by jarrah forest, October 1997, K.E.C. Brennan (Western Australian Museum specimen number T54593).

### ACKNOWLEDGEMENTS

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# Guide to Authors

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Reviews, observations and results of research into all branches of natural science and human studies will be considered for publication. However, emphasis is placed on studies pertaining to Western Australia. Longer papers will be considered for publication as a Supplement to the *Records of the Western Australian Museum*. Short communications should not normally exceed three typed pages and this category of paper is intended to accommodate observations, results or new records of *significance*, that otherwise might not get into the literature, or for which there is a particular urgency for publication. All material must be original and not have been published elsewhere.

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Numbers should be spelled out from one to nine in descriptive text; figures used for 10 or more. For associated groups, figures should be used consistently, e.g. 5 to 10, not five to 10.

Spelling should follow the *Concise Oxford Dictionary*.

Systematic papers must conform with the International Codes of Botanical and Zoological Nomenclature and, as far as possible, with their recommendations.

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